Inclusive Kerbs Study

Phase 2

May 2023

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Glossary

Ambient light	Light that is spread over an area/environment.
Ambient noise	Noise that is spread over an area/environment.
Containment	Keeping errant vehicles within the carriageway.
Crossfall	The gradient across the breadth of a surface.
Cycle track	A length of surface dedicated to cycling e.g., cycleway or cycle path. As defined in Transport Scotland's Cycle by Design 2021
Decibel	A unit used to measure the intensity of a sound.
Delineation	The act of showing the exact position of a border or boundary.
Depth of flow	Depth of water above the road surface.
DMRB	Design Manual for Roads and Bridges.
Dropped kerbs	Kerbs that are lowered at a road crossing or access to a property.
Flush	Two surfaces adjacent to each other and at same level.
Framework	The supporting structure for the system.
Functionally Impaired / Functional Impairment	A person who has a level of difficulty in completing daily living tasks and activities.
Gradient	The degree/steepness of a slope.
Longfall / Longitudinal	The gradient along the length of a surface.
Methodology	The method used to gather information in a study or activity.
Preview distance	The distance which someone may see an object before getting close to it.
Qualitative	A study method which uses metrics which are difficult to measure or quantify e.g., information or feedback.

Quantitative	A study method which uses metrics which can be measured and quantified, e.g., survey data or population statistics.
Reflective light	The light reflected from a surface
SRRB	Scottish Road Research Board
Topography	The physical landscape of an area
Upstand	The portion of the kerb that is raised above the carriageway

Executive summary

Scope and Purpose

The Inclusive Kerbs Phase 2 research project gathered data from kerbs within Edinburgh to understand what kerbs are present in the city and how people with disabilities use them. The study was conducted by Mott MacDonald and Edinburgh Napier University’s Transport Research Institute. It was commissioned by Transport Scotland on behalf of the Scottish Road Research Board and the Department for Transport.

Phase 1 of the project looked at existing research and found that there are few studies on inclusive kerbs considering both engineering and human factors.

Phase 2 gathered data and tried out selected methods to learn more about how people use kerbs. The study considered how kerbs are used for navigating along a street and for crossing the street.

Methodology

The researchers revisited the literature review from Phase 1 to check if there were any new papers since the first review. Then they looked at the different factors that affect how kerbs are designed, then studied them in real-world locations. They surveyed twenty-six locations across Edinburgh, which were chosen as representing a good mix of different types of kerbs.

Five of these locations were presented to people with disabilities in online interviews using different kinds of media like photos, videos, and sound. This was a pilot study to test out how to conduct future interviews. Two people with severe visual impairments participated in the interviews, one of whom was not based in Edinburgh. The researchers also used quantitative research to define what makes a more effective kerb, taking into account factors like the level of disability, personal adaptation, personal assistance, and street conditions.

Findings

The study focused on collecting data and testing interview methods for future research. Not all the data can be used to draw conclusions yet, but it can be developed in further investigations. The report presents findings where data and interviews are connected.

The interviews and studies looked at how people use kerbs. From the data and the interviews, it was found that: the contrast between the kerb and road/footway is usually low, the noise levels depend on the road type and use, some people with severe visual impairment aren't greatly affected by kerb height if they can detect it with a cane.

The interviews with the visually impaired participants also provided information on how they navigated the streets. They described the importance of surface texture and noise in situational awareness, how they produce a mental map of the routes and that changes to the street can cause problems, the difficulty of finding low kerbs with a cane, the difficulty in hearing approaching cyclists and electric vehicles, and the lack of safe crossings on cycle tracks and a lack of taught techniques and experience with crossing of cycling facilities.

Population data was also studied and showed that 21% of the population identify as having some form of impairment, including stamina, mental capability, hearing, and vision. This is a significant proportion of the total population.

Recommendations

The Phase 2 study did not produce any conclusive recommendations on kerb heights and layouts due to its limited nature. Therefore, it is recommended that further research should be carried out using the data gathered from the kerb surveys and pilot interviews.

The next stage of the study will extend to collecting data from people with moderate to mild impairments. This will be done through site visits with volunteer participants. Information gathered from these visits and interviews can be compared against the survey data to identify any patterns in experience.

1 Introduction

1.1 General

This report documents the process and findings of the Inclusive Kerbs Phase 2 research project. The project was commissioned by Transport Scotland on behalf of the Scottish Road Research Board (SRRB) and the Department for Transport and was conducted by Mott MacDonald and Edinburgh Napier University's Transport Research Institute. This phase establishes the basis for recommended future studies.

A requirement for improved inclusion for the roadside environment in future updated standards introduces a necessity for the study and reference of a wider range of functional impairments, not just registered disability. Hence, this study considers the larger and wider population of people who are functionally impaired in vision, hearing, physical movement, cognitive ability, and systemic impairments.

The study may lead to the change of existing, or development of new, guidance for Scotland, the UK, and beyond; it has therefore been designed to be as robust and rigorous as possible within project constraints to stand up to scrutiny and challenge. To achieve this, the project has used the latest available data to determine the proportions of the general population with functional impairment. This will inform future studies on sample sizes to represent the Scottish population when sampling functional disabilities.

To better serve the end user of any proposed kerb guidance, the project had a strong focus on the personal experiences of the roadside users with functional impairments. Utilising the analysed population data, the project recruited a small number of early interview participants from the highest impairment severity category to assist in pilot interviews. This initial feedback has been used to assist in the method development that can be used to help shape future research methods.

The project surveyed a range of existing kerbs in different locations collecting data on a range of attributes on kerb properties and its setting. The data gathered is used in the interviews and allows limited associations to be made between experiences of kerb interactions and kerb design.

1.2 Scope and objectives

Phase 1 of the study completed a literature review and recommended that a second phase be conducted looking at kerb boundaries between footways and carriageways, footways and cycle tracks, and cycle tracks and carriageways. This phase examined the key kerb boundaries identified in Phase 1 and how users interact with them.

This Phase 2 of the study examined these interfaces and how users interacted with them. It gathered necessary data and trial methodology to form a basis for recommending future studies on inclusive road design. It considered the whole setting and use of the kerb for navigation parallel along a street and as a point of uncontrolled crossing. The study provides a basis upon which future research can be built.

The study incorporated quantitative research to define appropriate kerb height provision, taking into consideration a full range of street users and impairments. The research approach considered the level and type of disability, the level of personal adaptation and degree of personal assistance, as well as street conditions.

1.3 Methodology overview

The project methodology is explained in greater detail throughout the report. An overview of the methodology is presented here:

A literature review was conducted in 2020 to establish if additional documents had become available since Phase 1.

The process of kerb design was considered to inform the study and assessment of the kerbs in-situ.

Kerbs were surveyed from twenty-six locations selected across the City of Edinburgh, gathering data on the kerb and the ambient conditions of the location. Edinburgh was selected as a representative sample of a Scottish urban area with a good diversity of kerb designs easily accessible for the project team.

Publicly available data on the population was analysed and categorised by severity and impairment.

Available volunteers from the ‘severe’ impairment category were presented with five of the surveyed locations in online interviews using verbal descriptions, photos, video, and sound.

The information found from the interviews and the literature review was compared against the data gathered on the kerbs and locations to determine associations.

All work was conducted to Edinburgh Napier University integrity, ethical and data management standards.

1.4 Report structure

In section 2 this report shall present a summary of the refreshed literature review, with the full review available in appendix A.

It will then present, in section 3, further discussions on the considerations when selecting kerbs in design. These will expand on some topics discussed in Phase 1.

Sections 4 and 5 will present the methodology, findings and discussion on the research and surveys conducted. Section 7 will present the data used to determine sample sizes to represent the Scottish population.

The conclusions and recommendations are presented in section 8.

Further data and analysis of kerbs is presented in appendices B and C, with appendices D, E, and G providing more information on the interviews and difficulty categories. Appendix F presents a detailed analysis of participants' demographics and disability characteristics.

2 Literature review update summary

2.1 Introduction

The Phase 1 literature review found minimal evidence of specific studies relating to kerb heights, with only two papers identified with a clear research basis. The first paper, 'Effective Kerb heights for Blind and Partially Sighted People' (Childs, et al., 2009), documented laboratory research in relation to what constitutes an appropriate upstand for pedestrians with visual impairments. The second paper, 'How does the edge height of curb ramps obstruct bicycles?' (Hayashi, et al., 2012), appraised ramped access for cyclists at footway crossover locations.

Numerous design policies, standards and guidance documents were reviewed as part of Phase 1. For any given kerb boundary type, each document often gave different kerb heights and did not provide justification for the dimensions stated. For example, at the key boundary between footway and vehicular carriageway (not at a crossing or footway crossover location) a 60mm height was commonly recommended. Most documents did not give a reason for the specified kerb height, but some did reference the Pedestrian Accessibility Movement and Environment Laboratory study (Childs, et al., 2009). Accordingly, there would appear to be a gap in the reasoning behind specified kerb heights.

The revised Phase 2 literature review revisited the published literature with a more general overview of kerb infrastructure research and conducted a review of the specific research associated with footways, kerbs and crossings and the interfaces with cycle facilities. The review found additional literature which was of interest to the project. The full literature review update can be found in appendix A.

2.2 Summary

In addition to the findings of the Phase 1 literature review, the key findings from the Phase 2 literature search can be summarised as follows:

- The extended literature search confirms that, in general, research into accessible kerb height design is limited, of low quality and often focusses only on one impairment with potential negative consequences for other users.
- Low lighting levels are associated with longer distances to see and recognise kerbs in older adult groups and those with age-related sight impairment, such as macular degeneration. The effects are particularly pronounced when descending kerbs, where movements can be expected to be adjusted to the low light.

- Increasing kerbside footway crossfall and gradient is associated with increased discomfort perception in wheelchair users and those using a cane or crutches. Excessive crossfall is likely to be problematic particularly when combined with longitudinal grade changes (along the road length); the suitability of localised increases above 2.5% is subject to debate.

3 Design considerations

3.1 General

The application of kerbs is mainly led by existing design standards and guidance. In the UK there are several sources which will influence the choice of kerb design. UK wide these include the Inclusive Mobility guidance (Department for Transport, 2021), Manual for Streets (Department for Transport, 2007) and Manual for Streets 2 (Department for Transport, 2010), several Local Transport Notes, and the Design Manual for Roads and Bridges (DMRB) (Standards for Highways, 2022).

Scotland's guidance includes Transport Scotland's Roads for All (Transport Scotland, 2013), Cycling by Design (Transport Scotland, 2021), and the Scottish Government's Designing Streets Policy Statement (Scottish Government, 2010). Further, each local authority, such as the City of Edinburgh Council, will have their own local design guides (City of Edinburgh Council, 2022).

Wales and Northern Ireland also have their own national guidance.

Depending on the road, a designer may need to use some or all of the above to determine acceptable kerb, footway, carriageway, and cycle track dimensions.

Available geometry, as well as functional, and aesthetic requirements of the street space, define the design choices of kerbs.

3.2 Profile

The profile, or shape, of a kerb was discussed in Phase 1. Some common kerb edge profiles include:

- Square – kerb comes to a point on outside edge
- Bullnose – slightly rounded on outside edge
- Full Batter – cut to chamfer 76mm x 76mm on outside edge
- Half Batter – cut to a slight chamfer on outside edge

Square nosed kerbs provide a sharper edge and provide some deterrent against vehicles crossing (CD 127 (Standards for Highways, 2021)). However, this edge is more exposed to damage.

In locations where it is expected the kerb may get more wear, the bullnose, and half batter, with their softer edges, may provide longer life. Full batter kerbs provide some chamfering which may assist movement of pedestrians or wheeled transport.

Cycle tracks are increasingly designed using splay kerbs as upstands to delineate them from footways, to prevent cyclists from catching their pedals on kerb edges. An example is shown in Figure 3-1 and Figure 4-2 below.

Figure 3-1: Splay kerb on Piershill

3.3 Delineation

Delineation is the act of showing the exact position of a border or a boundary (Cambridge University , 2022). This could be the boundary between a carriageway, cycle track or footway. It therefore can be considered an important aspect in the safety and inclusivity of design choices. It its therefore common to use kerbs between locations where there are areas intended for different uses, such as modes of transport.

Cycling by Design (Transport Scotland, 2021) states that where pedestrian and cyclist facilities are provided separately, they must be separated by a grass or paved strip, a kerb, or painted lines. It further states that the grass or paved strip should be one metre minimum in width.

Trapezoidal raised white lines of 20mm in height can also be used to separate pedestrian and cyclist facilities on segregated facilities, as prescribed in Schedule 9 of the Traffic Signs Regulations and General Directions 2016 (Department for Transport, 2016).

However, from Local Transport Note: Cycle infrastructure design (LTN 1/20), these trapezoidal strips may be disregarded by pedestrians and are difficult to maintain. This guidance recommends a kerb at least 50mm high to allow detection by cane and with a contrasting colour for those with visual impairment (Department for Transport, 2020).

3.4 Gradients

There are two gradients which affect the use of a footway, cycle track, or associated kerb. These are the crossfall and longitudinal gradients.

The longitudinal gradient is change in level along the footway, parallel to the kerb. This gradient is often dictated by the existing topography, but effort should be made to reduce as far as feasible. Inclusive Mobility (Department for Transport, 2021) guides us that a longitudinal slope should not be greater than 5% (18º), with anything greater being considered a ramp, requiring regular resting areas. However, existing infrastructure often has gradients significantly above this for prolonged lengths.

Kerb dimensions have little impact on the longitudinal gradient, but they may impact the user experience of the footway if they are crossing a road on a significant longitudinal gradient.

The crossfall gradient is the change in level across the footway and carriage, from one side to the other. It should be sufficient to allow water to flow off the surface and into the drainage, but low enough to not cause problems to users.

Where drainage is necessary, the crossfall of the footway is preferred to between 1% (3.6º) and 2% (7.2º), with a maximum of 2.5% (9º) (Inclusive Mobility (Department for Transport, 2021)). However, the gradient of the crossfall in existing sites varies significantly.

When changing the crossfall of an existing surface, the constraints are:

- the existing entrance levels to adjacent properties,
- the existing or proposed carriageway level,
- the width of the footway, and
- any kerb height restrictions (such as utility cover, local standards, or drainage).

3.5 Surface water drainage

3.5.1 Kerb and gully

Kerbs are often used as an important tool in containing and directing water on the surface off the road carriageway.

As the surface water gathers, it increases in depth against the kerb. To prevent the water impacting upon the adjacent footways or cycle tracks a kerb height greater than the likely depth of water is required to channel the water toward collection points, such as gullies.

The depth of water expected adjacent to a kerb (known as 'flow depth') is dependent upon the area and the gradients of the collecting surface, the rainfall on the surface, allowed area over which the water gathers adjacent to a kerb (known as 'flow width'), and the spacing of the gullies.

Phase 1 of this study calculated that the flow depth for a standard designed trunk road carriageway is 25mm (assuming 1 in 40 (2.5%) crossfall gradient and maximum flow width of 1m) (CD 526 (Standards for Highways, 2020)).

This Phase 2 has assessed the extreme value of 1 in 15 (6.67%) for both longitudinal and crossfall gradient. This provided a resulting flow depth of 67mm, for a maximum flow width of 1m. Typically though, flow widths in urban areas would be limited to between 0.5m and 0.75m to minimise inconvenience to pedestrians and to minimise risk of spray from the road onto the adjacent footway or cycleway.

Using this as a guide, a kerb height above 25mm could be suitable in preventing surface water encroaching upon the footway or cycle track. However, heights of 75mm or above would prevent water over topping the kerb for more intense rainfall events.

3.5.2 Drainage kerbs

Combined drainage and kerb systems can be used in place of the traditional kerb and gully system. A combined kerb drain has a perforated face leading to a hollow core which allows storm water to be drained from the road surface along the length of the road through an incorporated drainage channel.

Drainage kerbs do not require the depth of excavation that the traditional drainage system requires, and drainage kerbs are often used at urban areas with a relatively flat gradient and where there is a high concentration of utility services (CD 524 (Standards for Highways, 2020)).

These kerb units come prefabricated with set sizes and dimensions. From an examination of available drainage kerb products online (Drainage SuperStore UK, 2022), there appear to be a wide array of dimensions and sizes available. Ranging from the lengths and depths as low as 50mm and 125mm respectively, to lengths and depths as large as 1500mm and 1025mm respectively.

3.6 Restraint

Half battered or bullnose kerbs with an upstand of 100mm or greater can act as a minor restraint against light vehicles at very low speeds, providing sufficient deflection to direct errant vehicles back into the carriageway. This is particularly appropriate in an urban environment and at corners where vehicles are expected to make sharp manoeuvres (CD 127 (Standards for Highways, 2021)).

However, kerbs do not act as a restraint against vehicles travelling at any meaningful speed. In some cases, a higher kerb upstand would have negative effects. In rural areas with higher speed traffic full batter kerbs with 75mm upstand are considered acceptable to allow vehicles to overrun the kerb and reduce the risk of overturning (CD 127 (Standards for Highways, 2021)).

3.7 Footway Parking

In Scotland, a ban on footway parking, parking at dropped kerbs and double parking is being implemented nationwide through parking prohibitions in part 6 of the Transport (Scotland) Act 2019 (Transport Scotland, 2021), although local authorities will have leeway to exempt roads (or sections of roads) from this rule by the Pavement Parking Prohibition (Exemption Orders Procedure) (Scotland) Regulations 2022.

In London on footway parking is prohibited under the Greater London Council (General Powers) Act 1974 (The Stationary Office, 1974) unless specifically exempted by administrative resolution and appropriate traffic signage.

These pieces of legislations make crossing the kerb to park on the footway illegal. However, in certain situations the requirement to deter parking on the footway through use of kerbs will still be required and lower kerb heights may increase the temptation for some motorists to park on the footway. Future studies may be required to establish if a ban on footway parking results in behavioural change, especially in low height kerb locations.

3.8 Summary

The findings of design considerations can be summarised as follows:

- Four common types of kerbs are Square, Bullnose, Full Batter and Half Batter.
- A delineator between 12mm and 20mm in height is currently prescribed for segregated cycle tracks in the Traffic Signs Regulations and General Directions 2016 (Department for Transport, 2016). However, some subsequent design guidance indicates such a low profile may be disregarded by pedestrians and is difficult to maintain.
- Footway crossfall gradients preferred not to exceed a maximum of 2.5% (9^{o})
- Footway longitudinal gradients preferred not to exceed a maximum of 5% (18^{o}), but many existing locations exceed this.
- Kerb heights of 100mm or greater are noted to act as minor restraints against slow moving vehicles.
- The Greater London Council (General Powers) Act 1974 (The Stationary Office, 1974) legally restricts the use of footway parking and similar legislation is being introduced in Scotland.

4 Kerb surveys

4.1 Overview

To establish the existing kerb characteristics which are encountered by footway and cycle track users, the project surveyed a range of existing kerbs in different locations across the City of Edinburgh.

These surveys were used to provide a representation of selected locations for the participant interviews, covered in section 5.3 and to correlate the lived experiences of user interactions with the kerb properties.

4.2 Site Selection Criteria

The choice of kerb survey location was determined by considering the urban geography, land use, street type, and age. To capture these variations, a matrix was produced which divided the city by these factors.

The city was divided into four geographic areas:

- Old Town,
- city centre,
- urban, and
- suburbs.

These geographic areas were then divided by the land-use found within each area and the approximate age of the area.

In March 2010 the Scottish Government published Designing Streets: A Policy Statement for Scotland (Scottish Government, 2010), the first such policy statement for Scotland. Later that year, Cycling by Design (Transport Scotland, 2011) was also updated. The year 2010 can therefore be perceived as an important year dividing between old and modern design policies. Two age groups were used, before and after 2010.

The land use and ages considered were:

- On street retail (all pre-2010)
- Commercial or mixed development (all pre-2010)
- Residential (pre-2010)
- New build commercial or mixed development (all post-2010)
- New residential development (all post-2010)

Within each of these areas the streets were divided by their assumed vehicle traffic levels into main streets and side streets. Main streets were chosen to be busier with more through and slow and carefully moving traffic. Side streets were chosen to be less busy in comparison to main streets in the same area.

Finally, for as many of these combinations as possible one or more of the three kerb scenarios which would be studied, identified from Phase 1, were located. These were the kerb interface between:

- Footway and vehicular carriageway (not at a crossing or footway crossover location)
- Segregated footway/footpath and cycle track and,
- Segregated cycle track and vehicular carriageway

An example each of these scenarios for as many of the matrix points as possible was identified using local knowledge verified by Google Maps and Google Earth Street View; twenty-six locations were identified and selected for further research.

The City of Edinburgh has a wide range of varying street environments, this allowed a comparative assessment of results from areas within the same city.

Each location was subject to an inventory survey where specific measurements were gathered to assess the local kerb and site characteristics.

4.3 Survey methods and measurements

An onsite survey of the kerb and its environment was conducted at each kerb location. The following metrics were measured at each site:

- Kerb upstand height, kerb profile, and kerb top width,
- Crossfall and longitudinal fall of the adjacent area (typically a footway),
- Ambient light and kerb and adjacent area contrast,
- Noise,
- Presence of parking and loading of vehicles,
- Geographic location and local context (including local land use characteristics),
- Condition of the kerb and adjacent surfaces.

The following tools were utilised to complete the above measurements:

Table 4-1: Kerb survey methods

Measurement	Tool	Method
Kerb width and height	Tape measure	Extended along width and height.
Footway and carriageway gradient	Trend Digital Level Box	Zeroed and placed parallel and perpendicular to kerb on footway and carriage.
Ambient light levels	ATP DT-8809A Data Logger Light Meter (Luxmeter)	Maximum and Minimum values measured in the 40k range at head height for spot measurement.
Kerb reflective levels	ATP DT-8809A Data Logger Light Meter (Luxmeter)	Minimum value measured in 4k range at 10cm from the measured surface (using tape measure). Footway, kerb, and carriageway measured.
Ambient noise levels	ATP DT-8851 Sound Level Meter (Decibel Level Meter)	Maximum and Minimum values measured at head height over 1 minute on automatic.
Video crossing of road	Go-Pro Hero 3+	Attached to head strap or held at head hight, recording 'point of view'. Road checked for traffic then crossed and returned.
Location	Moto g (9) plus using Alpine Quest application on Android OS	Using map features pin was aligned to location and screenshot take to capture co-ordinates.
Photographs	Kodak Pixpro FZ201	Photos of approaches, crossing, and kerb taken.

A template was produced to enable a standard survey recording procedure at all survey locations.

When recording the noise levels, using the decibel meter, the survey team logged the minimum and maximum noise levels for approximately one minute. The team selected appropriate moments which captured the general ambient noise values for the road, avoiding intrusive noises which would affect the study, for example, a member of the public speaking loudly near the device or singular load noises which would increase the recorded maximum above the normal.

Together with information for the interviews, photos of the site were taken facing all directions and a 'point of view' video and sound recording were taken of a member of the survey team looking both ways, crossing the road at the kerb location, turning around, looking both ways again and crossing back.

The surveys were conducted on three separate days spread over the course of several weeks. Weather conditions on each of the days were generally a dry overcast with periodic spots of sunshine. The surveys began at approximately 10am and lasted between three and four hours.

The survey results appear in appendix B and are discussed below.

4.4 Survey data results

The measured data discussed in section 4.3 was assessed using the same criteria used in the site selection matrix discussed in section 4.2. The height, gradients, contrast, and noise were assessed in isolation and by their geographic location, street type, area and age, and the delineation of the kerb.

4.4.1 Height

The height of the kerb upstands surveyed ranged from 40mm to 140mm above carriageway or cycle track level. Of the twenty-six locations surveyed 10 (38%) are 100mm or above and 13 (50%) are 85mm or under.

4.4.1.1 Delineation

Cycle track and pedestrian areas

The kerb measured on the Leith Walk cycle track was the lowest measured on the survey. The kerb upstand was recorded at 40mm and featured a chamfered profile, shown in Figure 4-1.

Figure 4-1: Leith Walk cycle track

From the survey, low kerbs appear to be found in new build pedestrian busy areas, such as Leith Walk. The next lowest locations, York Place and Elder Street, are both 55mm. At York Place the kerb again separated the footway from the cycle track. On Elder Street however the kerb separated the footway from the carriageway.

However, not all cycle track and pedestrian area kerbs are as low, as shown in Table 4-2 below. Eyre Place is a new build side street in a predominately pedestrian commercial area and has a kerb upstand of 80mm. The newly built segregated cycle track at Piershill has 85mm splayed kerbs on both sides.

Table 4-2: Cycle track kerb height and width

	York Place	Leith Walk	Eyre Place	Piershill
Width (mm)	150	230	135	120
Height (mm)	55	40	80	85

Figure 4-2: Piershill cycle track

Footway and carriageway

A wider range of kerb heights were observed at interfaces between footway and carriageway in comparison to interfaces between footway and cycle track. The lowest value starts at 65mm on the quiet Dundas Street and raises to 140mm at the busy High Street.

4.4.1.2 Geographic location

The kerb height range surveyed, for all delineations, at different geographic areas in the City of Edinburgh are shown in Table 4-3.

Table 4-3: Kerb height by geographic location

Geographical Area	Average Kerb Height (mm)	Minimum Kerb Height (mm)	Maximum Kerb Height (mm)
City centre	83	55	125
Urban	81	40	110
Old Town	104	70	140
Suburban	99	92	105

Distinct differences in kerb height ranges were observable in different geographic areas. For example, the Old Town features the highest kerb heights in both average and maximum, where historically high kerb heights have been retained.

4.4.1.3 Street type

For this survey within each location described in section 4.2 the streets were divided into two categories. Streets which were larger, perceived as busier, or had speeds of over 20mph were designated ‘main streets’. Smaller, less busy, and lower speed streets were designated ‘side streets’.

From Table 4-4 it can be seen that there is little difference between both the average kerb height and the range of kerb heights found at different levels of the road hierarchy. This suggests that other factors are determining the kerb properties.

Table 4-4: Street type and kerb heights

Road Level	Average Kerb Height (mm)	Minimum Kerb Height (mm)	Maximum Kerb Height (mm)
Main street	94	40	140
Side street	86	55	113

4.4.1.4 Land use and age

A designer’s choice of kerb may be influenced by the current or planned local land uses and the character of the receiving environment. Recognising that design standards and guidance have notably evolved, accordingly, the results are divided between pre 2010 and post 2010 periods, as described in section 4.2.

Table 4-5: Kerb height by area and age

Area and Age	Average Kerb Height (mm)	Minimum Kerb Height (mm)	Maximum Kerb Height (mm)
Commercial or mixed development (pre - 2010)	96	80	140
New build commercial or mixed development (post - 2010)	92	40	124
On street retail (pre - 2010)	87	55	125
Residential (pre - 2010)	83	65	105
New residential development (post -2010)	60	60	60

Table 4-5 indicates that the range of kerb heights is greatest in new build commercial or mixed development (post - 2010), suggesting that there is not a consistency in approach. Both new and old commercial and mixed developments have the highest average kerb heights.

On street retail areas and pre - 2010 residential areas have a similar average of kerb heights, with on street retail having a higher range of heights.

4.4.2 Gradients

As described in section 3.4 there are two gradients which influence the use of a road, the longitudinal and the crossfall gradients. The longitudinal gradient in particular is influenced by geography. We have therefore only compared the footway crossfall gradients surveyed against the road distinction (main or side street) and area use.

Surveyed crossfall and longitudinal gradient data are provided in appendix C.2.

4.4.2.1 Area and age

Table 4-6 indicates footway crossfall by area use and age, it suggests that crossfalls may be lower in more heavily pedestrianised areas but shows a general consistency in average crossfalls and crossfall range.

Table 4-6: Footway crossfall by area age

Footway crossfall by area age	Average Footway Crossfall (degrees)	Minimum Footway Crossfall (degrees)	Maximum Footway Crossfall (degrees)
Commercial or mixed development (pre - 2010)	1.5	0.1	2.6
New build commercial or mixed development (post - 2010)	1.7	0.8	2.9
New residential development (post -2010)	2.3	2.3	2.3
On street retail (pre - 2010)	1.6	0.3	3.5
Residential (pre-2010)	2.2	0.6	4.6

4.4.2.2 Street type

Table 4-7 indicates recorded footway and carriageway crossfalls by street type. The maximum crossfall was recorded as 7.6º (2.1%), this was measured on Thistle Street, which runs perpendicular to the prevailing topographical gradient. However, it can be seen that the average crossfall for footways do not vary significantly with street type.

Table 4-7: Crossfall by street type

	Footway			Carriageway		
Street type	Average (degrees)	Minimum (degrees)	Maximum (degrees)	Average (degrees)	Minimum (degrees)	Maximum (degrees)
Main street	1.5	0.1	3.5	1.4	0.3	5.3
Side street	1.9	0.3	4.6	2.5	0.3	7.6

4.4.3 Contrast

The visual difference in brightness of the kerb against the footway and the kerb against the carriageway may be an important factor in its detection by those with visual impairment.

During the surveys the ambient light and the light reflective from the footways, kerbs, and carriageways was gathered. As ambient light changes the quantity of light reflected also changes. To accurately identify the proportions of light reflected the surveyed values were baselined against the ambient using the method described in appendix C.3. This proportion of reflected light is called the '**contrast**'.

The examples in the sections below show that when the value of the contrast is further away from zero, in either a positive or negative direction, the kerb is more easily distinguishable. Whereas the closer the value is to zero, the more difficult it is to visually distinguish them.

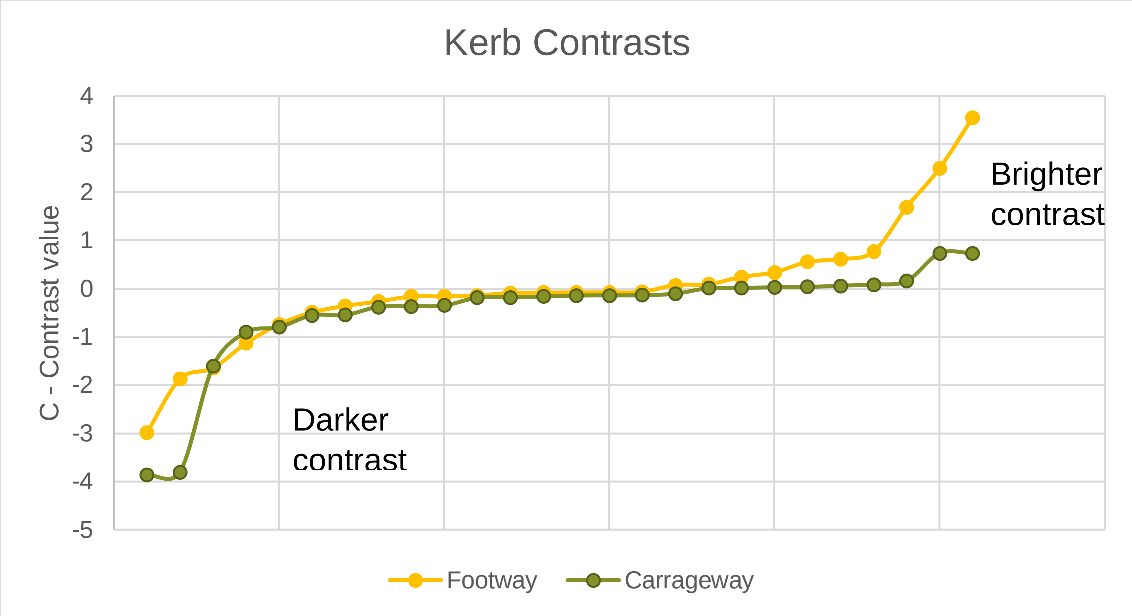
Table 4-8: Kerb contrasts by area

Kerb contrasts	Footway / Kerb Contrast			Kerb / Carriageway		
Land use	Average	Min	Max	Average	Min	Max
Commercial or mixed development (pre - 2010)	0.66	-0.74	3.55	-0.50	-3.86	0.74
New build commercial or mixed development (post - 2010)	0.23	-1.13	1.69	-0.79	-3.80	0.73
New Residential Development (post - 2010)	-0.07	-0.07	-0.07	-0.19	-0.19	-0.19
On street retail (pre - 2010)	-1.08	-2.99	0.24	-0.34	-0.90	0.09
Residential (pre - 2010)	-0.06	-0.36	0.56	-0.15	-0.35	0.06

Table 4-8 shows the contrasts of the kerb against the footways and carriageways for the different usage areas. It shows that the greatest range of contrasts is in the commercial and mixed development areas, and that all locations have a low average contrast. This can further be demonstrated by Figure 4-3.

When the values are positive the reflective value of the kerb is greater than the adjacent compaired surface, therefore brighter in contrast. When the values are negative the reflective value of the kerb is less than the adjacent compaired surface, therefore darker in contrast.

Figure 4-3: Kerb contrasts



4.4.3.1 Kerb and footway

For all photos the camera automatically adjusts contrast, the photos shown here are solely for illustrative purposes. Only the readings from the luxmeter are used in the assessment.

The location with the darkest contrast between footway and kerb was George Street with a value of 3.55, Figure 4-4: George Street.

The footway appears to be made from tan coloured stone slabs with the kerb being made from dark grey stone. There is a clear visual distinction between the kerb and footway here. The footway appearing as the darker element and the kerb as the brighter.

Figure 4-4: George Street

In comparison to the location with the brightest contrast value, Princes Street (Figure 4-5) with a -2.99 value, has the kerb made from grey stone and the footway made from tan stone slabs. There is still a clear visual distinction between the footway and kerb. Here the footway appearing as the brighter element and the kerb as the darker.

Figure 4-5: Princes Street

A street with a contrast value closest to zero would be Victoria Street (Figure 4-6) with a value of -0.1. The kerb on Victoria Street is made from a dark grey stone and the footway appears to be made from a similar dark grey stone slab. It is very difficult to distinguish between the footway and kerb here as they appear to be very similar in colour and darkness.

Figure 4-6: Victoria Street

4.4.3.2 Kerb and carriageway

The locations with the darkest contrast between the carriageway and kerb were Thistle and Elder Street with a value of 0.7.

On Thistle Street the carriageway is made from cobbles of varying colour and brightness, the kerb adjacent is a standard stone kerb of a dark grey colour. There is a slight visual distinction between the carriageway and kerb. Elder

Street is a new construction with kerbs that appear to be made from a dark grey stone whereas the carriageway is formed from flush ochre bricks. These can be seen in Figure 4-7 below.

Figure 4-7: Thistle Street and Elder Street comparison

Thistle Street

Elder Street

Constitution Street and Dundas Street (Figure 4-8) yield the brightest contrasting streets with -3.8 and -3.9 values respectively. For Constitution Street, the carriageway is black asphalt whereas the kerb appears to be a light grey drainage kerb. However, there is still a clear contrast between the carriageway and kerb however in this scenario the kerb is the brighter looking feature. To support this, Dundas Street kerbs are made from stone and appear to be grey, whereas the carriageway is made from a dark asphalt of varying patches of repair. Again, here the carriageway appears darker than the kerb.

Figure 4-8: Constitution Street and Dundas Street

Constitution Street

Dundas Street

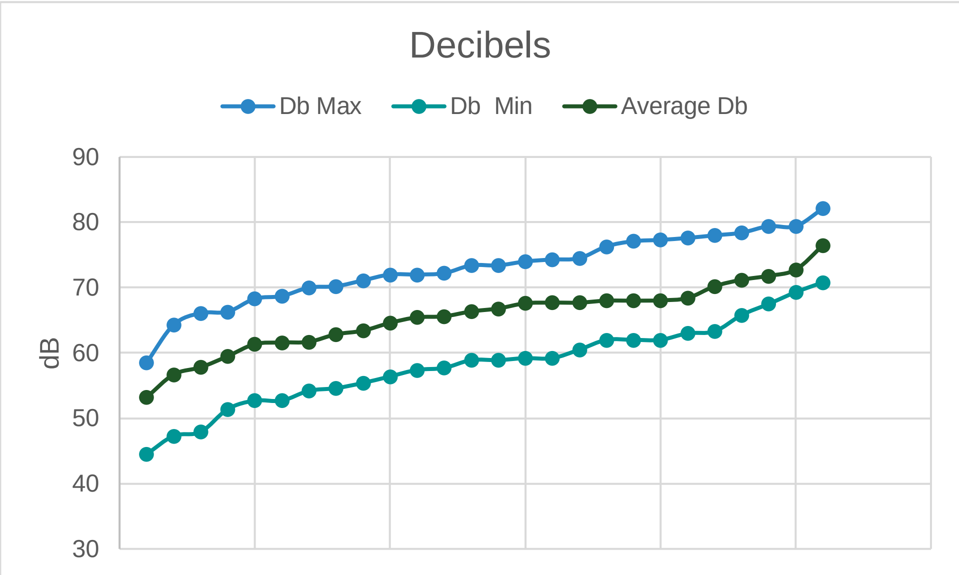
Victoria Street (Figure 4-6) sits on 0.01 contrast between carriageway and kerb. Victoria Street's kerbs are made from stone with the carriageway being made up from dark cobbles. There is very little visual difference between the kerb and carriageway here.

4.4.4 Noise

The ambient noise at each location, including maximum and minimum, were recorded in decibels for one minute. Across all sites this provided a range of noise levels from 44.5dB to 82.1dB, giving a range of 37.6dB, as can be seen in Figure 4-9.

On the decibel scale an increase of 10dB is a ten times increase in noise intensity. A quiet night-time bedroom level would be 30db, while next to a busy road would be approximately 90dB (Standards for Highways, 2020).

Figure 4-9: Decibel Readings



However, as shown in Table 4.9 the ranges within all areas are close to 26dB. The highest readings were found in established commercial or mixed developments, with on street retail the second loudest. Residential areas were found to have the lowest decibel levels.

Table 4-9: Decibels by area age

Decibels Recorded	Db Max	Db Min	Average Db	Range Db
Commercial or mixed development (pre - 2010)	82.1	52.7	66.98	29.40
New build commercial or mixed development (post - 2010)	78.0	51.4	65.84	26.60
New residential development (post 2010)	71.1	44.5	57.80	26.60
On street retail (pre - 2010)	79.4	55.4	68.85	24.00
Residential (pre - 2010)	73.4	47.3	59.28	26.10

Table 4.10 shows that the highest sound levels were found on the main streets, however the average noise levels and decibels were similar.

Table 4-10: Decibels by street hierarchy

Decibels Recorded	Db Max	Db Min	Average Db	Range Db
Main street	82.1	51.4	68.01	30.70
Side street	78.4	44.5	63.48	33.90

The full assessment of decibels by setting can be found in appendix C.5.

4.5 Summary

The finding of the kerb surveys can be summarised as follows:

- Cycle track kerb heights tended to be lower than the surveyed average and were chamfered.
- The average kerb height varied by geographic location, street type, areas usage and age. On average higher kerbs are found in:
  - the Old Town and suburbs,
  - Main streets, and
  - mixed use commercial and on-street retail areas.

  Lower kerb heights tend to be found in:
  - the city centres and urban areas,
  - side streets, and
  - residential and retail areas
- Kerbs tend not to have a significant contrast between the footway or carriageways.
- Commercial, retail areas, and main streets have the highest decibel readings, but all areas have a similar range of readings between highest and lowest.

5 Interview methodology

5.1 Introduction

A methodology was adopted to target key factors and risk groups. The framework for understanding the participants of the study and how they will interact with kerbs is based on the principles of inclusive design (Langdon & Thimbleby, 2010; Tennati et al, 2014; Langdon, 2014).

Inclusive design is a human-centred methodology that relates the capabilities of the population to the functional demands of a design. This introduces a necessity for reference to a wide range of functional impairments, not just registered disability (e.g., partially sighted, wheelchair users).

Currently, the median age in Scotland is between the ages of 43 and 50. This indicates that approximately half of the countries' population is over 50 years old. According to the Annual Report of the Registrar General of Births, Deaths and Marriages for Scotland (National Record of Scotland , 2018) these are the most rapidly increasing age groups. In many regions there has been an 4% increase in ageing between 2008-2018 and the fastest growth is seen in the 60-70 age group. Many regions are seeing up to a 29% increase in over 65's. These older populations contain a greater percentage of the functionally impaired community and a greater variation in sensory, cognitive, and physical user capabilities, particularly when non-age-related impairments are considered.

This section of the report describes the approach taken to interview the people that were recruited for the inclusive kerbs study. The overall aim is to look at improving street layouts for inclusion; hence, the project asked people who represent the functionally impaired population their opinions about, and experiences of kerbs during crossing and navigating along the street. The study team looked to engaged with people whose capabilities vary in the areas of vision, hearing, physical movement, or thinking ability. However, only two visually impaired volunteers were able to participate in this phase of the project.

Opportunistic, stratified, sampling (i.e., asking members of the stratified target population whether they would be willing to take part) was used to find participants for the pilot interviews in the phase. For detail on participant selection in this phase please see section 5.2.2

5.2 Participant personas

5.2.1 Overview

Each participant is representative of a ‘persona’ in terms of their functional impairment type, the severity of that impairment, age group, and identified gender.

In terms of functional impairment their personas have been categorised at different levels in:

- Vision
- Hearing
- Physical movement
- Thinking
- Systemic (overall capability)

The severity, based on difficulties experienced in daily life, which are imposed by impairments are then categorised are as follows:

- Category A – Severe
- Category B – Moderate
- Category C – Light to Moderate
- Category D – No difficulty*

*Assisted vision alone (e.g., glasses) is considered Category D.

Table 5.1 provides an example of the project classification using exemplars of the difficulty categories that have been employed based on functional ability and activities of daily living (Disability Resource Survey, Office of National Statistics, 2000). An expanded version of the table is included in appendix E.

Table 5-1: An exemplar of the capability descriptions for Category A (SEVERE)

Category A SEVERE	Difficulty Level	Level	Descriptive	Notes
	Vision	0	Not required to perceive anything by sight	
	Recognition	1	Required to recognise a friend at arm's length away	
	Hearing	0	Not required to perceive anything by hearing	
	Speech	1	Required to understand loud speech in a quiet room	
	Sounds	1	Required to follow a TV with the volume turned up	
	Physical Movement	1	Required to walk 50 metres (≈ 50 yds) without stopping	Or less e.g., wheelchair
	Steps	1	Required to manage one step	
	Balance	2	Required to balance for short periods of time, without holding on to something	
	Thinking	0	Not required to do something without forgetting what the task was whilst in the middle of it	
	sequence	0	Not required to hold a conversation without losing track of what is being said	
	Systemic*	0	Not required to walk	
	Locomotion*	0	Not required to bend down	
* Not an ONS scale				

The personas were divided by gender self-identification and age range:

- Young (16-44 years)
- Middle (45-64 years)
- Older (65-79 years)
- Senior (80+)

It is acknowledged that all categories of severity (A – D) could not be covered in this Phase 2 study, therefore this overview shall be considered as a guide to the study's intentions.

Section 7 Data Sampling, below, describes the methodology adopted to establish the prevalence of different severity levels in society from recent statistics.

As an integral part of the study, sampling included participants that represented inclusive populations with varying physical capabilities. For each persona, data was collected based upon the following characteristics:

- Struggles at physical interactions with kerbs and surfaces
- Physical, social and inclusion barriers (physical movement, visual, hearing, thinking etc.)
- Mental and physical workload
- Understanding and cognition
- Affect, apprehension and comfort in use

5.2.2 Proportional representation

For the purposes of recruiting participants for Phase 2 any combinations of impairment severity Category A, B, C & D, and the Functional Scales (Vision, Hearing, Physical movement, and Thinking), could be considered. Accordingly, as is conventional, opportunistic, stratified sampling was employed for qualitative interviews in this phase. This presented only two Category A (Severe) volunteers with functional impairment in vision for interview in this phase. This represented the older and younger age groups of the severe visual scale.

It is recommended that the goal of selection of participants in any subsequent research is to produce a result that is correlated to the prevalence of each sampling category in the Scottish population. The prevalence of each sampling category (severity x function x age x gender) is presented in section 7.

Qualitatively, the sampling strategy will allow the functional groupings of age groups, genders, and sites to be partially covered. All possible combinations of severity, functional impairment, gender, and age are unlikely to be realised and strategic sampling of the combinations considering impact and prevalence was conducted.

5.3 Methods

The interview methods were based on both the reflective lived experiences of the participant and their reactions to the data and commentaries from site surveys (section 4). The mixed methodology approach addressed numerical and verbal data collection targeted at key issues and technology developments. The study used a mixed method approach to the collection of evidence, as commonly used in social science studies. To this end, qualitative data in the forms of online interviews and commentaries from site visits, were considered in conjunction with statistical data on the prevalence of functional impairments in the population.

5.3.1 Procedure

The pilot interviews were conducted online with the available participants, one of the participants was not based in Edinburgh. One of the participants was from the Older (65-79) age group with the other being from the Young (16-44) group. The older participant was a trained cane user from an early age and sometimes had the support of a carer. The younger participant was a trained cane user, and frequently relied on support from seeing assistants for new routes.

It is generally recognised as best practice in inclusive design development that disabled communities are involved and included into the research process from the earliest stages. This enables participants to provide reflective comment and critique of the methodology and content of interviews which could then be taken account of when defining the actual methodology to be adopted for the research interviews. For this reason, the interviews undertaken in this phase were considered as 'pilot interviews' to allow for collaborative feedback on methodology and content from participants.

The interviews were undertaken and recorded utilising Microsoft Teams online meeting software, with interviewees responding from their own homes. One week prior to the interview date the consent forms, interview briefing, and interview schedule documents were sent by email to allow time for reading prior to the interview. Participants were asked to select the most familiar sites from the short list generated (Table 5-2) as representative of kerb situations in urban areas.

Table 5-2: Short list of sites for interview

	Location	Purpose in Study
Location 1	York Place	Cycling
Location 2	Elder Street	Pedestrianised
Location 3	High Street	High kerbs
Location 4	Constitution Street	New build / drains
Location 5	Buchannan Street	Quiet Road
Location 6	Dundas Street	Complex Road
Location 7	George Street	Pedestrianised

The interview process adopted was as follows:

- verbal consent was obtained from potential interviewees,
  - See appendix H for consent forms and interview briefing and schedule documents
- basic demographic questions were asked and recorded,
- the participant made self-assessment choices for each of the capabilities,
- the interviewer and participant held detailed discussion of the exemplar sites' information,
- the interviewer and participant discussed general related issues, and
- finally, the participants were invited for site visits if they were interested.
  - Contact details were retained in these cases.

Because participants may lack experience of areas in Edinburgh, an initial open question asked them to relate their experiences in crossing kerbs along with related difficulties in general. This unstructured, free-response item allowed prompting from the interviewer in a neutral way. This was followed by the interviewer reading from verbal descriptions taken from the kerb survey site survey. Pilot questions were interspersed to record the participant’s reaction to the interview schedule content.

During the verbal description (example Figure 5-1) the participants were encouraged to ask for clarification and make clarifying comments based on the suitability of the description. In some cases, audio recordings from the video crossing data (described in the methodology section 4.3) were played for each site to give a soundscape to assist understanding. A series of structured questions followed the site descriptions covering familiarity, attitudes to crossings, physical and mental workload, and abilities or difficulties in each of the functional areas.

Figure 5-1: An example of verbal site description

1 York Place – Outside the Playhouse

Approaching downhill from the Omni Centre, a widened plaza with steps narrows to a smaller plaza with different patterned slabs. The slabs are new, smooth and dark grey. A controlled pedestrian crossing on your left crosses the cycleway and the road. The tactile paving is close into the crossing point with no tail.

Turing left to facing the road behind you is the Playhouse Theatre. Infront is a line of slabs, flush with surrounding marking a change in angle of the footway as it slopes up to the cycleway. At the top of the slight slope there is a new low angled kerb down the cycleway. The cycleway is black asphalt and dark red chips, about 1.5m wide, with another low angled kerb up to a narrow cobbled strip segregating it from the carriageway.

You can hear a street with buses, lorries and cars continuously stopping and starting at, and driving through, the traffic lights and roundabouts nearby. There are pedestrians passing in sporadic frequency but not crowding. The occasional cyclist will approach and pass on the cycleway.

The area is wide open and exposed.

5.3.2 Qualitative analysis

The interview recordings were downloaded and transcribed using a secure automated subscription service. The resulting coding and frequency of occurrence of themes is summarised in appendix G.

The codes were reviewed for themes and patterns. The findings from these interviews are covered in secton 6 below.

5.3.3 Coding references

The qualitative data coding references in are represented heirarchically based on frequency and content.

These were coded to groups by subject and topic:

- Street Properties
  - Moving through streets, crossings, road types, kerbs
- Strategies [for navigation]
  - Tactics in street, cues for crossing, use of assitance, on the street
- Capabilities
  - Sound, cane, orientation, training,
- General Remarks

For the purpose of illustrating the collaboratative nature of the pilot trial, this was a restricted sample of two participants and was therefore not deemed to be representative of the wider population. However, future analysis will include this data, which will be recoded across the whole sample. The code frequency list and Heirarchy chart are used here to illustrate the method.

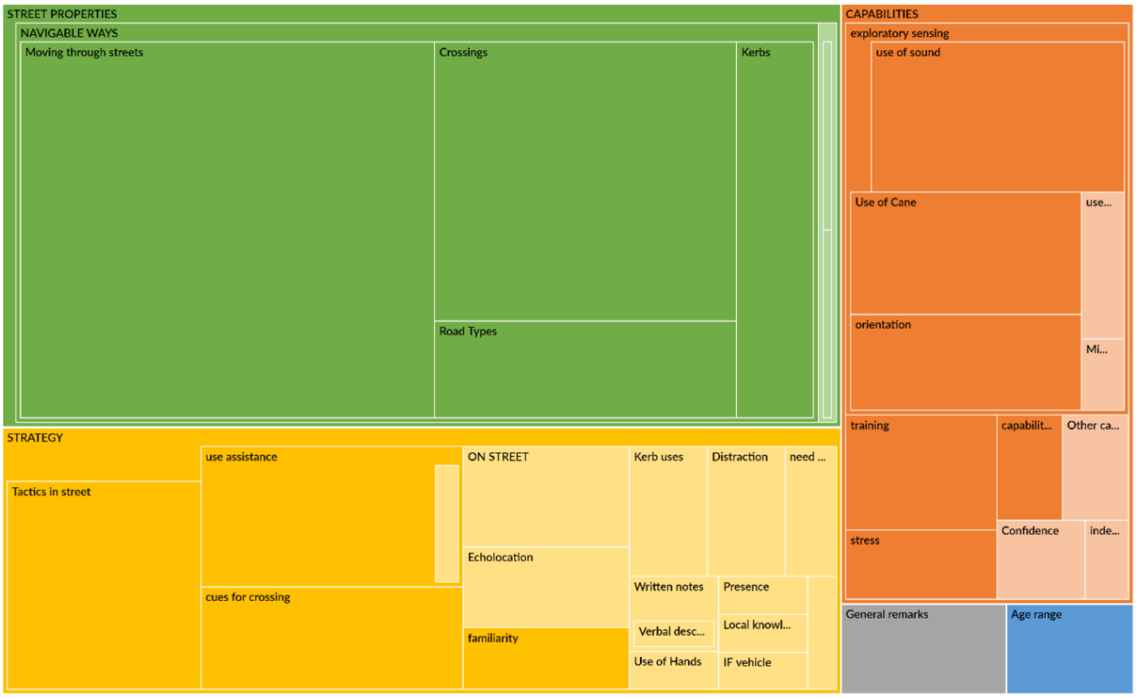
Methodology, such as meta-questions and procedures of interviews, were coded to ‘Method’ where appropriate and this is excluded from the qualitative analysis thereafter. The complete code table is included in Appendx .

The findings from these interviews is covered in section 6 Interview feedback .

Table 5-3: Top level code list

Name	Files	References
Strategy	2	82
Street Properties	2	58
Capabilities	2	15
Method	2	15
General remarks	2	4
Age range	2	3

Figure 5-2: Hierarchy area chart of frequency of coding references



6 Interview feedback

6.1 Introduction

The pilot interviews were conducted as described in the methodology in section 5. Their interview responses were coded as described in section 5, and are discussed under the code headings in the following sections.

In the interviews the participants of the pilot phase concentrated on discussing strategies for navigating the streets and around kerbs. Their second topic of concern was the properties of the streets that were presented.

Participant 'Capabilities' with respect to the task of negotiating kerbs was an area of discussion and there were a few 'General remarks'.

6.2 Navigation Strategies

The interview participants expressed a number of underlying strategies to their approach and interaction with kerbs.

A principal strategy adopted by some participants was the use of assistance from passers-by or sighted guides in the event of the person anticipating difficulties in navigation. Participants had a range of tactics available to employ dependent on circumstances, but it was clear that the use of such tactics were more developed in the older age bracket.

A key tactic adopted was establishing orientation with respect to the environment. This may be done using landmarks, compass directions, or sounds. The presence or form of kerbs can also influence orientational understanding. In some cases, kerbs are considered a weaker cue than other features in the environment, for example parked cars. Orientation is critical to establish a mental map which assists effective Situation Awareness (SA).

Other adopted strategies include the memorised location of a particular street, pedestrian areas, and objects and hazards to be navigated. Surface features are a key source of information, including surface gradient, surface colour contrast, and material properties such roughness (e.g., differences between stone, asphalt, grass). These surface features are detected using feet, canes, and hands.

A range of tactics using sound and echolocation (i.e., detecting objects in the environment by listening to the echoes from those objects) to help build SA were adopted by both participants. This utilised people's voices, sound echo, road noise, and other diverse sounds. Some participants created or referenced written descriptions of intended routes of travel and then employed a strategy of practicing the route allowing them to build SA and specific skills.

Both participants indicated awareness of the availability of accessible smartphone mapping applications, but the younger participant demonstrated a more detailed understanding and practical experience of use.

An awareness of unpredictable hazards and the necessity for readiness for them, was mentioned by both. The potential of encountering a vehicle whilst crossing a street was acknowledged as a common risk and, in this regard, vehicle noise was noted as a key factor for detection of the hazard.

6.2.1 Use of assistance

Assistance emerged as fundamental requirement for the participants. This ranged from accompaniment by a sighted person (e.g., a relative or designated guide), through to requesting help from passers-by at difficult points such as a complex junction.

It was stated by both participants that they would sometimes reject offers of help from passers-by as this was considered a distraction when attempting to self-orientate and to build a mental map, which required attention and focus. Some participants were trained in the best way to hold a person’s arm. For those with severe visual impairment, aid from another person was generally required to locate crossing assistance devices such as pedestrian push buttons. Sighted companions often carried baggage on behalf of those with severe visual impairment.

6.2.2 Cues for crossing

Among the many cues used by participants with severe visual impairment for developing SA, were those specifically for crossing. A key strategy was locating pedestrian crossings, traffic light crossings or other controlled crossings. This often involved a plan to locate the crossing using kerbs and tactile surfaces to determine the final location of a crossing point.

Kerbs were referenced in quieter roads to locate the road edge when walking along seeking a break in traffic. Other cues included gaps between parked cars, locations of bins, and pavement surface and width. Hands were employed for locating and contouring objects such as cars.

Sounds and echoes were deemed essential for confidence; the detection of sounds of approaching traffic was imperative for safety, including cars, trams, pedal cycles, and people.

Established crossings broadcasting sounds as bleeps or verbal information were preferred and this extended to haptic (i.e., tactile) devices (i.e., cones on the underside of the push button unit). Crossings without these features were considered intimidating.

6.2.3 Street tactics

Problems with streets included issues of location with respect to the street frontage, footway, lateral centreline, and obstacles to be manoeuvred around such as cafes and bins. This was especially difficult in wide open spaces, such as pedestrianised areas where the centre of the pavement was difficult to locate.

In quiet streets, the road noise sometimes presented a more comfortable cue for locating the centreline, but cycle tracks were problematic because of a perceived collision risk from both participants. Assuming good hearing, echolocation was perceived as of moment-by-moment value in maintaining SA. This helped to establish the ‘shoreline’ of shop or road frontage as opposed to the ‘sea’ of traffic and vehicles. By preference, users wanted to follow the footway centreline for optimal echolocation. Using the kerb for guidance was perceived as risky because of the possibility of encountering obstacles such as lampposts or wheelie-bins. Footfall, ambient noise, and cane noise were used in echolocation.

Tactile paving is often used to assist in locating an established crossing (as discussed in section 6.2.2). However, tactile paving was perceived as potentially unreliable, and location of kerbs was still important when finding crossing locations.

6.2.4 Familiarity

The participants were mostly familiar with their locale and routes through it. They maintained a mental map of the road crossing points, traffic lights and features and hazards, whether main roads or side streets. This familiarity allowed for an increased comfort and perception of personal safety. Unfamiliar areas included areas where occasional or weekly journeys would be made. These were perceived as within the range of possible routes, and exciting, with established memory of landmarks (e.g., Playhouse, RNIB). New routes were planned in advance and sighted assistants would be employed for initial attempts.

6.2.5 Distraction

Distractions can be detrimental to orientation for those with visual impairment. Those interviewees who used cane sounds and other noises for echolocation confirmed they required concentration and focus to maintain the high mental workload needed.

Noisy environments and loud noises, such as aircraft and roadworks, disrupted the echolocation process and distracted the user. This led to poor directional control and affected maintaining direction. This was often a problem at crossings or when locating kerbs for orientation.

Another source of distraction was conversational attempts by passers-by and offers of help.

6.3 Street properties

In general, a clear difference emerged for approaches to side streets and main streets in terms of crossing kerbs. Themes relating the properties of streets themselves have been identified here.

6.3.1 Navigable way

One key was the position of oncoming and passing traffic; particularly those vehicles which were silent and cannot be heard approaching. For example, cycles were considered virtually impossible to hear, especially on a cycle track adjacent to a carriageway, which may mask other sounds. Some cars were silent; especially at low speeds, making them difficult to hear at locations where traffic and pedestrians interact.

Interviewees reported that quiet roads were easier to navigate because traffic is less frequent making crossing less risky. Here, the identification of kerbs and their height was less important than other cues, such as parked vehicles.

Areas with flush or raised crossings presented hazards to those with severe visual impairment, this included low kerbs that were difficult to locate, presenting difficulties for navigation and orientation.

Another common hazard to navigation for those with severe visual impairment was the presence of temporary obstacles and relocation of objects used by the participants as landmarks, such as permanent bins, meaning that memorised mental maps become temporarily inaccurate or need to be changed.

Temporary obstacles, such as road works, were considered always unpredictable, and moveable bin locations could vary from week to week. Fixed areas, such as cafes, could also present difficulties with pedestrian overspill and variations to layout. Cars parked on footways were acknowledged, by both participants with severe visual impairment, as a hazard to orientation and movement, but could be a useful orientational cue if parked correctly on street.

As discussed in section 6.2.3, walls, frontages, doorways, drives, windows, and other common street features form what is commonly described as a 'shoreline'. Detecting the shoreline is important for SA, familiar routes are perceived as relatively safe but anything that distracts or changes can break the mental map and commonly results in the visually impaired street user to stop, retreat or 'hover' in a safer area, while rebuilding the mental map and reorientating.

Landmarks include physical shoreline features and what are commonly known as "seaside features" such as lamp columns, but also terrain attributes such as gradients and the tactile areas at crossing locations (discussed in section 6.2.2).

Large buildings and visual features are only recalled by reference to routes or descriptions, the visual features or architectural characteristics of a street are not used or remembered as they are too high or distant to be detected.

6.3.2 Pedestrian crossings

The interviewees perceived controlled crossing points as safer than uncontrolled crossings, especially if they incorporate accessibility features (as described as follows).

Generally, the more cues evident at a crossing location, the better it was perceived by participants with severe visual impairment. Features such as dropped kerbs and tactile paving spanning the full width of a footway were perceived as positive in terms of orientation, whilst the lack of such features often caused ambiguity and trepidation.

At controlled crossing locations, features such as automatic recognition of pedestrian demand and/or audible bleeps or vocal messages when safe to cross were considered as excellent by both participants in many situations. When progress was being made along a street using a cane and whilst searching for a crossing, any cues on the kerb (such as drop down) that were detectable with the cane indicating that there was a crossing, were perceived as detectable and beneficial.

However, at complex crossing locations (such as large junctions) such features were sometimes confusing as the purpose and location of the broadcast signal may be unclear. At some controlled crossing locations traffic light sequences were unpredictable and sometimes had to be memorised. The lack of assistance features for those with visual impairments at a controlled crossing location was perceived as considerably raising the risk of using the crossing. At such crossings the use of sighted assistance was often required to navigate the cross or to locate the haptic equipment (cones) on the push button unit.

Because visually impaired people build and rely on SA or a mental map, using the cane to find the kerb during progress along a pavement whilst searching for a crossing, provides additional cues that indicate the approach to an established crossing. These additional cues (dropdowns) were perceived as beneficial.

Features perceived as negative were those which made the crossing area less distinct from the footway by making the levels to be the same as other street areas, such as raised walkways or ramps across the carriageway.

6.3.3 Cycle tracks

Cyclists are difficult to detect by sound and their approach can be masked by adjacent noise such as a passing vehicle. There was a perception that marked crossing points of cycle tracks for pedestrians were not common and that there was a lack of controlled pedestrian crossing points over cycle tracks. The perception was that cyclists had priority over pedestrians.

The risk of collision with a cyclist was universally perceived as a high-risk situation. This was particularly the case when cycle tracks were not clearly delineated from footways by kerbing or when pedestrians were required to cross the cycle track.

Vertical marker posts on cycle tracks were perceived as useless at delineating the boundaries for visually impaired people.

The intersection in Glasgow between Elm Bank / Sauchiehall Street (Google Maps, 2022) was discussed in one interview as an example of where flushed crossing without tactile paving of cycleways prevent visually impaired pedestrians from identifying the difference between footway, cycleway, and carriageway. A quote from the interview describing this can be found in Figure 6-1. The full quote can be found in appendix I.1.1.

"…you have to worry if you want to cross the whole width of the cycle way and the road and the carriageway"

Figure 6-1: Cycleway crossing quote

Similar issues were mentioned regarding the lack of orientation cues on central reservation areas to determine correct crossing points between carriageways at crossings and between cycle tracks and carriageways.

6.3.4 Road types

Side roads are perceived as categorically different from main roads, as crossing is easier and presents different situational challenges. Kerb heights are perceived as unimportant as numerous other objects separate users from infrequent traffic. Kerbs can, however, be uneven in depth and height with channelled drains and gratings presenting hazards to navigation. The carriageway and footway may also be uneven, with potholes, puddles, and raised covers, making cane use less useful.

"… there's a bit of a tension between whether to try and walk on the pavement in spite of all the planters and bike racks and shop displays and stuff, or to walk down the middle and hope that you'll hear the traffic on the crossing road before you step out into it. "

Figure 6-2: Pedestrianised area quote

Pedestrianised areas were perceived as particularly problematic. In the interviews the participants identified street furniture and clutter in the pedestrian space as challenges to their navigation. This made walking in the centre of a pedestrianised road easier than walking on the building frontage. However, a major safety concern was the lack of transition or notice change from the pedestrian space to a vehicle carriageway in the centre of the pedestrianised road space. A quote from the interview describing this can be found in Figure 6-2. The full quote can be found in appendix I.1.2.

Some surfaces, such as grass, appear to be perceived as a cue to refuge areas but tactile surfaces are deemed untrustworthy and susceptible to damage by contractors. Tram tracks on roads were not noticed, mainly because the strategy would be to locate a managed crossing when trams were a potential hazard.

6.3.5 Kerbs

Dropped kerbs were acknowledged by the participants as useful cues to the location of crossings but should be sufficient in gradient to be detected. They were perceived by the participants as useful for other road users, such as wheelchairs.

In the interviews visually impaired participants did not perceive kerb height as important if the kerb was high enough to be detected by a cane severely. Above the hight detectable by a cane was not considered to be additionally beneficial. A quote from the interview describing this can be found in Figure 6-3. The full quote can be found in appendix I.1.3.

> **"I don't think the kerb needs to be that high for my purposes … As long as it's consistent and distinctive"**

Figure 6-3: Kerb height quote

However, kerbs were perceived as necessary to mark the boundaries of a cycle track. Kerb drains were perceived as irrelevant if the kerb itself was distinct.

6.4 Capabilities

6.4.1 Exploratory sensing

Building and utilising mental maps were the main means of orientating for effective and safe traversal of streets or locating and using crossing opportunities.

The location, shape, and gradient of kerbs and surfaces is mainly detected using long-cane techniques. Training for this promotes a technique of scanning the surface ahead using a wrist-flick arc during movement and entails various tip attachments, such as balls, to allow for sensing of bumps and ridges. Canes cannot identify head-height obstacles. Canes can catch on edges such as potholes and this can be painful and dangerous as the cane pushes back on the body.

Sensing is also heavily sound dependent, hence dependent on reasonable hearing (one participant had both visual and mild hearing impairment). Using active signals from footfall and cane tapping, users can build an active picture by echolocation of nearby objects. This is most effective on either side of the user rather than in front or behind. It is most useful in navigating a straight line along a pavement in a built-up area where users are generally presented with an assortment of objects on their left or right. The cane can be used to profile kerbs and get approximate sense of kerb depth. This is enhanced and complemented by foot contact (Eduardo et.al., 2015). A quote from the interview describing this method can be found in Figure 6-4. The full quote can be found in appendix I.1.4.

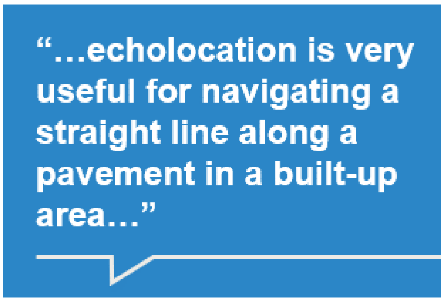


Figure 6-4: Echo location quote

Passive hearing of sounds, allows direction, distance, and movement of objects, such as vehicles, cyclists, and people, to be perceived. Combined with active sensing this builds a sensory picture of the environment that is centred on the person and a not fixed orientation, such as compass points. This sensory picture is constantly changing with movement, enhancing detection of objects, and it is likely that this is critical to the formation of the elements of the spatial situational awareness.

Cues in a person's environment are necessary to aid them in orientation. These cues could include objects, echolocation, edges and kerbs, gradients, and materials underfoot. Small edges can be difficult to detect and therefore do not aid orientation. These cues can help to build SA and are used in conjunction with cues recalled from past experiences or descriptions from others. SA or Situational awareness is like a moving Mental map.

However, building, orientating, and maintaining this picture during movement in the street is a high workload cognitive activity and easily disrupted by attempts at talking or other noises, such as from vehicles, dogs, or machinery.

At crossings the differences between carriageway and footway are generally self-evident, particularly when tactile surfaces are correctly situated. However, alignment may drift during the movement of crossing placing the person at risk and resulting in them requiring assistance (from a stranger or accompanying person) to re-orientate.

At complex crossings without assistive technology the process is hard work and stressful, although this is counterbalanced by a common desire to practice new routes. The approach to crossing locations is generally well signalled by the presence of dropped kerbs.

6.4.2 Orientation

Orientation is a critical ability that is a learnt skill using available information. This includes surface gradients, kerb locations and slopes, and shoreline echolocation. Tactile surfaces are used to orientate and can be helpfully used in conjunction with slope and kerb sensing. Prior knowledge and familiarity are used to populate the mental map, as can route descriptions, or phone based navigational apps, if effective.

6.5 General remarks

The above interpretations of thematic content of the participants of the study only reflect the Severe visual category, although it does sample two age groups: the Older (65-79) and Young (16-44) groups. These pilot interviews were also purposed as collaborative research, in that the participants were encouraged to constructively criticise the methods of interview.

Some key criticisms were that participants were not familiar with the sites selected in the project survey and that therefore their appreciation of the verbal descriptions was fragmentary. This was not aided by the references to visual landmarks or properties.

However, positive remarks were made about the use of audio files taken from crossing at each site. These stereo recordings were generally considered to be effective, particularly if listened to with stereo earphones. The recordings were sent to participants as sound files but not all proprietary formats were usable. The idea of 3D printed tactile maps to describe locations or crossing routes was perceived as a good approach and this may be testable. Finally, navigation map smartphone apps were considered to be an exciting prospect, but applications known to the participants (Google Maps, Soundscape, and Blind Square) were not considered effective.

6.6 Summary

In understanding participants and their experiences, the pilot interviews can be summarised as follows:

- The methodology of the interviews produces participant ‘persons’ based on their functional abilities and impairment severity (categorised A – D), their age and self-identified gender.
- Interviews were conducted as tests/pilots to gain feedback and allow improvement.
- Interviews were initially conducted involving participants with visual impairment in Category A (SEVERE), covering two age ranges (65-79) and (16-44).
- Interviews were set up to understand lived experience and knowledge from the participants.

- Interviewees were asked about their perceptions of a selection of the surveyed kerb locations and about general kerb use and street navigation.

  Visually impaired users described:
  - the ‘shoreline’ and ‘sea’ method and the importance of surface texture and noise in situational awareness.
  - how they produce a mental map of the routes and that changes to the street can cause problems.
  - difficulty finding low kerbs with a cane, and flush kerb are impossible.
  - difficulty in hearing approaching cyclists and electric vehicles, and the lack of safe crossings on cycle tracks.
- There is a lack of taught techniques and experience with crossing of cycling facilities.

7 Data Sampling

7.1 Data source

The project has used the latest available data to determine the proportions of the general population with functional impairment. This allowed us to understand what proportion of people are affected by visual, hearing, movement, systemic, and intellectual difficulties at various degrees and over what range of age groups and by gender. This can be used in future studies to establish a sample size representative of the various levels of functional disabilities in the Scottish population.

Data was drawn from the Family Resources Survey, 2019-2020 (National Statistics, 2021) (available through the UK Data Service), the most comprehensive and recent data collection, and filtered for Scottish respondents (n= 4467)

Like any other data included in the UK Data Service, the dataset was subjected to rigorous and comprehensive processing and curation. Several variables relating to the disability status of the respondents were extracted from the Family Resources Survey and analysed. These include the reported difficulties of the respondents with a range of capabilities (e.g., vision, hearing, mobility, and dexterity, etc.) and their associated socio-demographic characteristics.

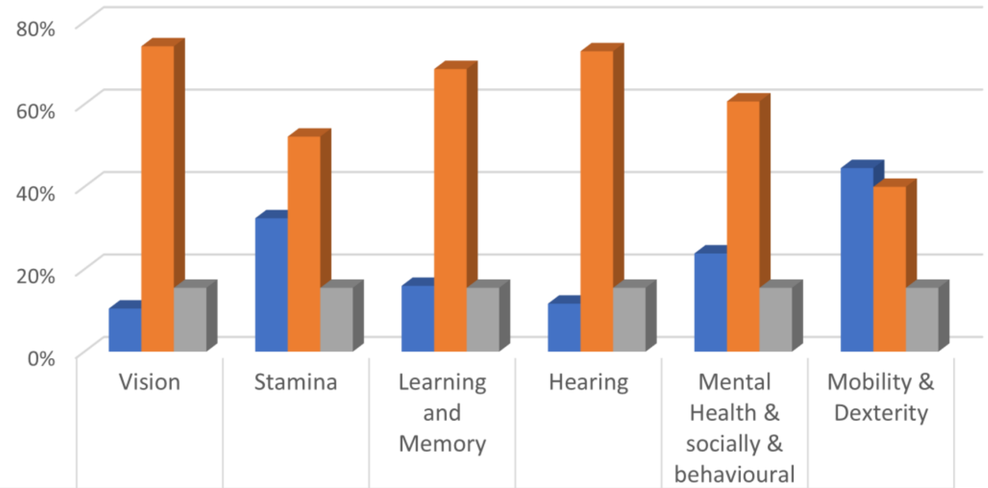
The dataset from this survey consists of information from 4467 respondents in Scotland, of which nearly 50%, 2086 responses, have varying levels of difficulties relating to different types of capabilities: vision, stamina, learning and memory, hearing, mental health, social and behavioural capabilities, mobility, and dexterity.

7.2 Difficulties & capabilities

The data from the Family Resources Survey provides information vision, stamina, learning and memory, hearing, mental health, social and behavioural capabilities, mobility, and dexterity.

Figure 7-1, below, shows the proportions of respondents having difficulties with diverse types of capabilities. Appendix F.1 provides a more detailed breakdown.

Figure 7-1: Proportions of sampled respondents with difficulties by capability type



	Vision	Stamina	Learning and Memory	Hearing	Mental Health & socially & behavioural	Mobility & Dexterity
Yes	10%	32%	16%	12%	24%	45%
No	74%	52%	69%	73%	61%	40%
None	15%	15%	15%	15%	15%	15%

Yes No None

The outcome “Yes” denotes the proportion of people having difficulty with a particular capability (some respondents may or may not have difficulties with other capabilities too). The outcome “No” denotes proportion of people who do not have a difficulty with a particular capability, but they have difficulties with some other capabilities. The “None” outcome, constant at 15%, indicates the respondents who do not have difficulties with any of the listed capabilities.

Mobility and dexterity are associated with the highest proportion of respondents that face difficulties. Specifically, 929 respondents, 45%, have difficulties with mobility and dexterity; 834 people (40%) have no difficulties with mobility.

Difficulties by age and gender are presented in appendix F.2 and F.3 respectfully.

The levels of hindrance on everyday activities have been presented in appendix F.

7.3 Summary

The findings of the Data Sampling can be summarised as follows:

- Data for the quantitative study was drawn from Family Resources Survey (2019-2020).

- Provides data on the prevalence of various levels of capability of the key functional scales in the Scottish population, which can be used in future studies to establish a representative sample size.
- The percentage of difficulties from the data survey were:
  - 45% Mobility & Dexterity
  - 32% Stamina
  - 24% Mental Health & social & behavioural
  - 16% Learning and Memory
  - 12% Hearing
  - 10% Vision
- When distributed by age older age groups were more likely to report difficulties.
- When distributed by hinderance Mobility & Dexterity was shown to be the greatest reported difficulty in reducing activity, followed by Stamina.

8 Conclusions and recommendations

8.1 Conclusion

The study has focused on gathering data and piloting an interview methodology in preparation for future research. At this stage, not all data or information can be linked to a conclusion and the findings produced are tentative. However, they may be developed with further investigations.

The limitations of the Phase 2 study should be noted when considering the results provided. The sites were all within one city and the total sample of sites is twenty-six, resulting in only a limited range of locations surveyed. The pilot interviews involved two available participants whose capabilities aligned with the severe visual impairment category. The interviewees were from the Older (65-79) and Young (16-44) age ranges. The interviews were conducted online allowing one of the participants to not be based in Edinburgh.

From these studies it can be concluded that the key factors which affect kerb height and form are standards and guidance, the urban location, and when it was installed.

On average, higher kerb heights in Edinburgh tend to be found in:

- the Old Town and suburbs,
- main streets, and
- mixed use commercial and on-street retail areas.

Lower kerb heights in Edinburgh tend to be found in:

- the city centres and urban areas,
- side streets, and
- residential and retail areas

Interviews and studies around the setting and use of kerbs has found that:

- The contrast (as defined in section 4.4.3) of the kerb against the carriageways and footways is generally a low value; meaning the kerb is similar shade to one or both.
- The noise levels of the locations surveyed (as defined in section 4.2) vary depending upon road distinction and use, but the noise range is similar.
- From the interviews there is a perception from some participants with Category A (Severe) visual impairment that they are not greatly influenced by the kerb height, provided it is detectable by a cane.

The studies of the population data, to determine proportional representation in future studies, indicates that there is a significant percentage of the Scottish population, 21%, who identify as having some form of mobility and dexterity impairment.

8.2 Recommendations and Further Studies

Due to the nature of the Phase 2 study no definitive recommendations on kerb heights and layouts can be made.

However, it is recommended that there is continued research utilising the data gathered from the kerb surveys and building upon the pilot interviews.

Future studies should continue to acquire data in the moderate, and mild to moderate categories. The studies should aim to address the range of impairments across physical movement, hearing and thinking capabilities, as well as systemic (overall) difficulties as far as practicable.

More complete data should be collected using site visits with volunteer participants from the impairment groups. Then the accumulated qualitative themes should be integrated with quantitative data from sound and light luminance measurements at each site, in the context of video and photographs.

It is recognised that a wider geographic range may yield more results and that each city and region has differing, sometimes historic, kerb installations. A wider range of kerb locations could be considered in future studies.

Future studies could also include situational impairments, such as shopping bags, baby carriages, wheelchairs, and mobility scooters, under controlled conditions. Under these conditions further studies could include controlled comparisons of kerb properties, such as profile (splay kerbs, half batter kerbs and square edge kerbs) and contrast. Variations in ambient and environmental factors such as illumination, noise, precipitation, and seasonal change could also be further considered.

The minimum level of kerb detection by a visually impaired person using either a cane or a guide dog could also be considered.

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A. Literature review update

A.1 Introduction

The Phase 1 literature review found limited study into the kerb heights, with only two research papers identified with a clear research basis. 'Effective Kerb Heights for Blind and Partially Sighted People' (Childs, et al., 2009) had carried out laboratory research in relation to what constitutes an appropriate upstand for pedestrians with visual impairment. 'How does the edge height of curb ramps obstruct bicycles' (Hayashi, et al., 2012) appraised ramped access for cyclists at footway crossover locations.

Numerous design policies, standards and guidance documents were reviewed. For a given interface, each often gave different kerb heights and did not provide justification for the dimensions stated. For example, at the key interface between footway and vehicular carriageway (not at a crossing or footway crossover location) there was commonly a 60mm height recommended. Most documents did not give a reason for the specified kerb height. Accordingly, there would appear to be a gap in the reasoning behind specified kerb heights.

In summary, the following key findings emerged during Phase 1:

- Only some of the design standards, policies and guidance considered specified kerb heights and ranges.
- Only two academic papers were identified that specifically researched kerb heights.
- Only two design policies, standards, or guidance documents, in addition to the September 2021 revision to Cycling by Design (Transport Scotland, 2020), cited academic research as the basis for kerb height guidance.
- There are multiple instances where standards, policies or guidelines specify kerb upstand heights and ranges without citing supporting evidence. Those which do often cite the Pedestrian Accessibility Movement and Environment Laboratory research (Childs, et al., 2009).
- Specified kerb heights and ranges are often dependent on kerb profile and adjacent features.
- A 60mm upstand is generally considered to be an appropriate standard kerb height that can be reliably detected by people with sight impairment, but it is not yet certain as to whether a 50mm height kerb is similarly effective.
- There appears to be clear benefits for cyclists through the implementation of chamfered kerbs at track edges, though the suitability of such installations for pedestrians with various forms of disability is not yet ascertained.
- A 25mm raised kerb height at footway crossover locations is generally accepted as suitable to allow a vehicle to drive over at low speed.

- At pedestrian crossing locations, a 6mm maximum upstand is appropriate, where a flush kerb cannot be provided.
- The design of bus stops is a specialist multi-factored area, where kerb heights are not the only factor affecting accessibility.
- Public realm design is complex, and multi-factored, where associated interface or pedestrian 'comfort space' (or 'safe area') edge delineation design and specification should not be considered in isolation.
- Under the Equality Act 2010, the Public Sector Equality Duty (PSED) requires public bodies to have due regard to the need to eliminate discrimination, advance equality of opportunity and foster good relations between different people when carrying out their activities. This includes the duty to make reasonable adjustments if disabled people are put at a disadvantage. It is, therefore, crucial to be inclusive in the design of kerb installations and to recognise the practical importance of consistency and familiarity for disabled street users. The study notes there is a broad range of road users that have some form of disability or mobility impairment that may be impacted by kerb height, including non-physical impairments such as mental health, age, and certain conditions such as diabetes. To be truly inclusive, kerb height and form design should account for as wide a range of disabilities (user types) as possible, whilst acknowledging there may be conflicting influences between some user types.

Furthermore, in the Phase 1 Report, there were three key interfaces that were identified as areas that required further study. These interfaces were:

- Footway and vehicular carriageway (not at a crossing or footway crossover location)
- Segregated footway/footpath and cycle track/cycle track and,
- Segregated cycle track/cycle track and vehicular carriageway

This revised literature review revisits the published literature with a more general overview of kerb infrastructure research, a review of the specific research associated with footways, kerbs and crossings and the interfaces with cycle facilities.

A.2 Overview of kerb infrastructure research

Kerbs are an integral part of road infrastructure and provide a variety of functions, including providing structural support, channelling surface water away from the carriageway, discouraging parking and driving on the footway, re-directing slower moving vehicles, providing visual carriageway edge delineation, and contributing to the aesthetic of the urban environment. The height a road kerb has should be such that the kerb can absorb torsional (i.e., twisting) loads from vehicles and resist tilting; however, design guidelines on the structural analysis of kerbs are sparse and as such it has been suggested that specification of kerbs internationally tends to be on an ad-hoc basis (Momotaz et al., 2022). The maximum height of a kerb has also been associated with the road design speed, particularly for higher speed roads, primarily for the reasons of vehicle stability. In the United States, vehicle kerb traversal tests resulted in recommendations for a maximum height of 150mm for design speeds up to 85kph with a maximum of 100mm for any speeds exceeding this (Plaxico et al., 2005).

In urban areas vehicle speed is less likely to be an issue in kerb design other considerations such as accessibility and footway protection are of greater importance. Gamache et al. (2019) undertook a meta-review of literature on pedestrian infrastructure with a specific focus on the needs of disabled users and assessed the quality of evidence available. Forty-one articles were identified with objectively measurable infrastructure guidance (e.g., height, width, gradient) from a pool of 1,131 that were obtained using a defined set of associated keywords. Notably, the quality of articles was found to be low in both quantitative and qualitative terms. Articles tended to focus on a single impairment, meaning that their findings could not be generalised to all users. A lack of standardisation of methods was also noted and unresolved contradictions between recommendations were found. Pertinent to this present work, the reviewed literature focussed mainly on dropped crossings alone with no specific reference to full kerb height. One positive that could be taken was that most articles to be reasonably recent and findings therefore could be considered generally representative; nonetheless, the review indicates the area of inclusive kerb height appears to be poorly understood in the wider context.

A.3 Visibility and step height of kerbs

One consideration in the accessibility of kerbs is the ability of users to detect them using sight, or residual sight in the case of visually impaired users. Alexander et al. (2014) undertook a study to determine how changes in ambient light affected the ability of age-related macular degeneration to negotiate kerbs. The work featured ten adults with macular degeneration and a control group of eleven fully sighted subjects performing a kerb negotiation task in normal and low light conditions (circa 600 lux and 0.7 lux respectively). In normal lighting those with macular degeneration were found to use shuffling steps when descending kerbs, an approach not adopted by the same group when ascending them. In reduced lighting, both user groups were found to adopt adjusted kinematic approaches, adopting a more cautious approach to kerb negotiation. The work highlights the importance of ambient lighting and the tonal contrast of kerb edges, particularly in users sensitive to the consequences of a fall.

A similar study was undertaken by Cheng et al. (2018). In this case, thirty-one subjects of which 16 were older (65-74 years) and 16 were younger (25-34 years) performed a step task in a simulated laboratory environment. The task investigated four step heights, including those associated with a typical kerb height, where visual fixations were measured using eye-tracking glasses. Tests were undertaken using two different light levels (4 lux and 200 lux) which corresponded to minimum and maximum acceptable illuminance for street lighting. The work found an association between the lower light level and reduced detection distance in older people when compared with the younger group. Descending steps was found to be particularly challenging for the older group; this was a similar finding to those of Alexander et al. (2014) for those with age-related macular degeneration previously described. The findings suggest that higher levels of lighting are important in the urban environment to highlight features such as kerbs, particularly where they are being descended.

A.4 Footway-to-kerb crossfall

For reasons of stability, footway crossfall is a potentially important consideration for pedestrians accessing or egressing the footway across a kerb, or whilst walking or wheeling parallel to it. A literature review of practice in the United States showed that despite American accessibility guidelines recommending a maximum crossfall of 2%, no research or history could be found to support reasoning behind the figure (Kockelman et al., 2000). It was noted the figure may be in practice too strict for footway crossings and driveways, although no reference was made to full-height kerbs. In a follow-on study, empirical data was gathered from a sample of 67 subjects, including cane, wheelchair, crutch, and leg-brace users across a range of age groups (Kockelman et al., 2002). The subjects traversed test sections of footway, with heart-rate changes measured as a proxy for effort, along with user discomfort perception. The study found cane and crutch users perceived the most difficult, followed by manual wheelchair users. It was suggested that crossfalls greater than 2% could be considered in certain circumstances, such as vehicle crossovers.

The specific case of wheelchair users and crossfall has been investigated through application of a Capability Model approach (Holloway & Tyler, 2013). The Capability Model considers both provided and required capabilities and is concerned primarily with body function. In this case, the model was used to map interactions between the person, wheelchair, and the public realm environment. Twelve non-disabled participants and two regular wheelchair users were asked to traverse paths of varying crossfall values (0% to 4%) in a laboratory. An instrumented wheelchair was adopted in the study to measure three-dimensional forces applied by the user. On average it was found that a linear increase in difference in work was required as crossfall gradient increased; for example, for the UK standard of 2.5%, this meant a 50 Nm difference in work, rising to 200 Nm for 10% crossfalls as advocated in other literature. Such considerations are particularly relevant where changes in crossfall occur, such as at kerb transitions or where a wheelchair user joins a footway perpendicularly with a longitudinal gradient.

A.5 Cyclist/pedestrian kerb height interactions

The previous sections investigated literature in relation to the footway-carriageway interface. Whist difficult to quantify due to the limited collision data available, it has been suggested that footway-cycle track kerbed interfaces might also introduce a hazard worthy of consideration (Janssen et al., 2018). The consequent study considered kerb height, slope, and type; in addition, the colour difference between cycle track and kerb was recorded. Over 14,000 cyclist and 3,000 pedestrian interactions with kerbing were observed at 12 locations in Amsterdam. Logistical regression modelling was performed to test the effect of the variables recorded. The significant relationship regarding cyclists and pedestrians was the kerb type; levelled kerbs were associated with changes in heights, slopes or colours having no associated effect. It was also noted that incursions were more prevalent on curved sections when compared with straight sections; this suggests pedestrian and cyclist desire lines may explain preferences in kerb traversing behaviours.

A.6 Summary

In addition to the findings of the Phase 1 literature review outlined in the introduction to this chapter, the key findings from the updated literature search can be summarised as follows:

- The extended literature search confirms that, in general, research into accessible kerb height design is limited and often focusses only on one impairment with potential negative consequences for other users.
- Low lighting levels are associated with decreased preview distance and recognition of kerbs in older adult groups and those with age-related sight impairment such as macular degeneration. Effects are particularly pronounced when descending kerbs, where people’s approaches can be expected to be altered.
- Increasing kerbside footway crossfall and gradient is associated with increased discomfort perception in not only wheelchair users but also those using a cane or crutches. Excessive crossfall is likely to be problematic particularly when combined with longitudinal grade changes; the suitability of localised increases above 2.5% is subject to debate.

B. Kerb survey data

B.1 Day 1 Survey Data

B.1.1 Location, Visual, Dimension and Incline data

Metric Measured	York Place	Leith Street	High Street	Gentle's Entry	Holyrood Road	Blair Street	Stevenlaw's Close	Cowgate	Victoria Street	Elder Street
General	Day 1 Survey Results									
Date	26/01/2022	26/01/2022	26/01/2022	26/01/2022	26/01/2022	26/01/2022	26/01/2022	26/01/2022	26/01/2022	26/01/2022
Time	9:57am	10:22am	10:49am	11:17am	11:34am	11:53am	12:12am	12:27pm	12:44pm	1:15pm
Location data										
Weather conditions	Overcast, dry	Overcast, dry	Overcast, dry	Overcast, dry	Overcast, dry	Overcast, dry	Overcast, dry	Overcast, dry	Overcast, dry	Overcast, dry
Coordinates										
OS National Grid	NT 26079 79420	NT 25934 74095	NT 21961 73662	NT 26560 73682	NT 26363 73557	NT 25949 77346	NT 25906 73491	NT 25763 73455	NT 25492 73451	NT 25789 74204
Latitude / Longitude	55.957083 N 03.185394 W	55.95934 N 03.187721 W	55.950272 N 03.157177 W	55.950540 N 03.177599 W	55.949383 N 03.180707 W	55.998793 N 03.187317 W	55.948725 N 03.188008 W	55.948378 N 03.190295 W	55.998298 N 03.194624 W	55.955119 N 03.190161 W
Speed Limit / Traffic Restrictions	20mph Pedestrian Crossing Cycleway	20mph Pedestrian Crossing Junction	20mph Traffic lights	20mph Junction Single lane	20mph Pedestrian Crossing	20mph	20mph Junction Single lane	20mph One way (temporary)	20mph One way	10 mph
Kerbside parking	No	No	Taxi rank	Taxi rank	Yes / disabled	Yes	No	No	No	Yes
Loading / Unloading	No	Loading only	Loading	No	No	No	No	No	Yes	Yes
Visual data										
Carriageway material	Ashphalt	Ashphalt	Cobbles	Cobbles	Ashphalt w/ black chips	Cobbles	Cobbles	Ashphalt	Cobbles	Cobbles
Kerb material	Concrete	Concrete	Stone	Stone	Stone	Stone	Stone	Stone	Stone	Stone
Kerb shape	Chamfered	Square-nosed drain	Square-nosed	Square-nosed	Square-nosed	Square-nosed	Square-nosed	Square-nosed	Square-nosed	Square-nosed
Footway material	Concrete slabs	Stone slabs	Stone slabs	Stone slabs	Ashphalt w/ white chips	Stone slabs	Ashphalt w/ white chips	Ashphalt	Stone slabs	Concrete slabs
Cycleway material	Ashphalt w/ red chips	N / A	N / A	N / A	N / A	N / A	N / A	N / A	N / A	N / A
Kerb measurements										
Width (mm)	Top: 100.0 Bottom: 150.0	150.0	300.0	300.0	150.0	140.0	155.0	125.0	140.0	145.0
Height (mm)	55.0	100.0	140.0	124.0	113.0	104.0	70.0	85.0	95.0	55.0
Incline (Degrees)										
Crossfall										
Footway	1.1	0.8	2	0.8	2.9	1.4	4.6	1.3	2.2	1.9
Carriageway	3.8	1.3	0.4	0.5	1.4	3.4	4.3	0.7	2.4	0.8
Longfall										
Footway	2.6	3.8	3.8	0.5	2.7	7.7	2.8	2	6.9	5.4
Carriageway	2.8	7.6	2.7	0.4	0.8	7.91	8.6	1.8	6.5	5
Crossing Complexity Rating	3	5	4	1	3	5	2	3	3	1

B.1.2 Luminance and Noise data

Metric Measured	York Place	Leith Street	High Street	Gentle's Entry	Holyrood Road	Blair Street	Stevenlaw's Close	Cowgate	Victoria Street	Elder Street
General	Day 1 Survey Results									
Date	26/01/2022	26/01/2022	26/01/2022	26/01/2022	26/01/2022	26/01/2022	26/01/2022	26/01/2022	26/01/2022	26/01/2022
Time	9:57am	10:22am	10:49am	11:17am	11:34am	11:53am	12:12am	12:27pm	12:44pm	1:15pm
Luminance										
Lux (40k) Max	2.4	3.9	5.0	5.6	6.0	2.8	3.2	3.2	4.8	9.2
	236.0	388.0	497.0	564.0	595.0	276.0	323.0	322.0	475.0	919.0
Lux (40k) Min	2.3	3.8	4.9	5.7	5.9	2.5	3.2	3.2	4.7	9.1
	227.0	380.0	493.0	572.0	591.0	247.0	319.0	319.0	473.0	910.0
Reflectied @ 100mm (4k) Max										
Carriageway	101.0	161.0	261.0	320.0	257.0	139.0	208.0	115.0	164.0	690.0
Kerb	119.0	184.0	224.0	311.0	252.0	206.0	201.0	97.0	161.0	525.0
Footway	141.0	201.0	200.0	329.0	224.0	325.0	134.0	75.0	135.0	673.0
Bave	231.5	384.0	495.0	568.0	593.0	261.5	321.0	320.5	474.0	914.5
Contrast										
Contrast - Carriageway	-0.6	-0.6	-0.5	-0.4	-0.6	-0.5	-0.4	-0.6	-0.7	-0.2
Contrast - Kerb	-0.5	-0.5	-0.5	-0.5	-0.6	-0.2	-0.4	-0.7	-0.7	-0.4
Contrast - Footway	-0.4	-0.5	-0.6	-0.4	-0.6	0.2	-0.6	-0.8	-0.7	-0.3
Real Contrast										
Carriageway / Kerb	-0.1	-0.1	0.2	0.0	0.0	-0.5	0.1	0.1	0.0	0.7
Kerb / Footway	0.2	0.1	-0.1	0.1	-0.1	-1.9	-0.4	-0.1	-0.1	0.6
Calculated Reflected differences										
Carriageway / Kerb	18.0	23.0	37.0	9.0	5.0	67.0	7.0	18.0	3.0	165.0
Kerb / Footway	22.0	17.0	24.0	18.0	28.0	119.0	67.0	22.0	26.0	148.0
Carriageway/Footway	40.0	40.0	61.0	9.0	33.0	186.0	74.0	40.0	29.0	17.0
Decibel - 1 minute										
Db reading Max	74.0	76.3	77.1	70.2	78.0	78.4	73.4	73.4	64.3	68.3
Db reading Min	62.0	58.9	63.3	65.8	67.5	57.7	62.0	62.0	58.9	57.4

B.2 Day 2 Survey Data

B.2.1 Location, Visual, Dimension and Incline data

Metric Measured	Buchanan Street	Leith Walk	Manderston Street	Pattinson Street	Constitution Street	Eyre Place Banana Row Studios	Dundas Street	Thistle Street	George Street	Frederick Street	Princes Street
General	Day 2 Survey Results										
Date	02/02/2022	02/02/2022	02/02/2022	02/02/2022	02/02/2022	02/02/2022	02/02/2022	02/02/2022	02/02/2022	02/02/2022	02/02/2022
Time	9:57am	10:17am	10:37am	11:02am	11:21am	12:32pm	12:54pm	1:17pm	1:29pm	2:00pm	2:07pm
Location data											
Weather conditions	Overcast, dry	Sunny, dry	Sunny, dry	Overcast, dry	Overcast, dry	Overcast, dry	Overcast, dry	Overcast, dry	Overcast, dry	Overcast, dry	Overcast, dry
Coordinates											
OS National Grid	NT 26707 75205	NT 26743 75490	NT 26897 75731	NT 27468 76746	NT 27307 76401	NT 25330 74978	NT 25218 74483	NT 25379 74123	NT 25379 74034	NT 25181 73870	NT 25219 37831
Latitude / Longitude	55.964238 N 03.175379 W	55.966806 N 03.175160 W	55.968996 N 03.172748 W	55.973709 N 03.163754 W	55.975670 N 03.166389 W	55.961994 N 03.197742 W	55.957427 N 03.199308 W	55.954113 N 03.197417 W	55.953518 N 03.196602 W	55.952017 N 03.199778 W	55.951673 N 03.199099 W
Speed Limit / Traffic Restrictions	20mph	20mph	20mph	20mph	20mph Temporary lights	20mph One way	20mph	20mph	20mph Road closed temporarily	20mph	20mph
Kerbside parking	Yes	No	Yes	Yes	Yes / Disabled	Yes	Yes	Yes	No	Taxi rank.	No
Loading / Unloading	No	No	Yes	No	Loading Only	Loading Only	Yes	No	No	Yes	No
Visual data											
Carriageway material	Ashphalt	Ashphalt w/ black chips	Ashphalt	Cobbles	Ashphalt w/ black chips Concrete Tramway	Ashphalt w/ white chips	Ashphalt	Cobbles	Ashphalt	Ashphalt w/ black flakes	Ashphalt + Concrete Tramway
Kerb material	Stone	Concrete	Stone	Stone	Concrete	Stone	Granite	Stone	Stone	Stone	Stone
Kerb shape	Square-nosed	Chamfered	Square-nosed	Square-nosed	Square-nosed drain	Square-nosed	Square-nosed	Square-nosed	Square-nosed	Square-nosed	Square-nosed
Footway material	Ashphalt	Concrete slabs	Stone slabs	Ashphalt w/ white chips	Stone slabs	Ashphalt w/ red chips	Concrete slabs	Ashphalt w/ white chips	Concrete slabs	Concrete slabs	Stone slabs
Cycleway material	N / A	Ashphalt w/ red chips	N / A	N / A	N / A	Ashphalt w/ red chips/surfacing	N / A	N / A	N / A	N/A	N / A
Kerb measurements											
Width (mm)	125.0	Top: 230.0 Chamfer: 30.0	145.0	120.0	125.0	135.0	150.0	130.0	155.0	155.0	300.0
Height (mm)	65.0	40.0	105.0	60.0	110.0	80.0	85.0	80.0	85.0	75.0	125.0
Incline (Degrees)											
Crossfall											
Footway	2	1.2	2.3	2.3	2.5	1.8	1.1	0.7	0.8	0.3	3.5
Carriageway	2.9	0.7	0.5	2	0.6	3.9	0.4	7.6	5.3	0.3	1.1
Longfall											
Footway	0.7	0.8	0.3	0.7	0	0	4.4	0.5	0.6	3.7	0.2
Carriageway	0.8	2.3	0.4	3.2	0.8	0.2	4.7	0.5	0.7	2.9	1.1
Crossing Complexity Rating	4	9	5	3	4	4	10	4	5	9	8

B.2.2 Luminance and Noise data

Metric Measured	Buchanan Street	Leith Walk	Manderston Street	Pattinson Street	Constitution Street	Eyre Place Banana Row Studios	Dundas Street	Thistle Street	George Street	Frederick Street	Princes Street
General						Day 2 Survey Results					
Date	02/02/2022	02/02/2022	02/02/2022	02/02/2022	02/02/2022	02/02/2022	02/02/2022	02/02/2022	02/02/2022	02/02/2022	02/02/2022
Time	9:57am	10:17am	10:37am	11:02am	11:21am	12:32pm	12:54pm	1:17pm	1:29pm	2:00pm	2:07pm
Luminance											
Lux (40k) Max	5.5	5.7	6.3	3.8	6.2	7.4	4.2	4.7	5.8	3.7	4.1
	553.0	572.0	634.0	383.0	618.0	740.0	424.0	466.0	583.0	367.0	406.0
Lux (40k) Min	5.2	5.0	5.1	3.8	6.1	7.3	4.2	4.4	5.7	3.6	3.9
	520.0	496.0	514.0	377.0	614.0	731.0	419.0	438.0	571.0	360.0	389.0
Reflectied @ 100mm (4k) Max											
Carriageway	267.0	444.0	292.0	134.0	570.0	446.0	371.0	372.0	374.0	191.0	255.0
Kerb	315.0	516.0	399.0	180.0	745.0	493.0	566.0	313.0	486.0	347.0	307.0
Footway	235.0	670.0	524.0	166.0	664.0	453.0	980.0	178.0	557.0	389.0	443.0
Bave	536.5	534.0	574.0	380.0	616.0	735.5	421.5	452.0	577.0	363.5	397.5
Contrast											
Contrast - Carriageway	-0.5	-0.2	-0.5	-0.6	-0.1	-0.4	-0.1	-0.2	-0.4	-0.5	-0.4
Contrast - Kerb	-0.4	0.0	-0.3	-0.5	0.2	-0.3	0.3	-0.3	-0.2	0.0	-0.2
Contrast - Footway	-0.6	0.3	-0.1	-0.6	0.1	-0.4	1.3	-0.6	0.0	0.1	0.1
Real Contrast											
Carriageway / Kerb	-0.2	-0.8	-0.4	-0.2	-3.8	-0.2	-3.9	0.7	-0.6	-0.9	-0.4
Kerb / Footway	-0.3	-1.1	2.5	-0.1	1.7	-0.1	-0.7	-0.5	3.6	-1.6	-3.0
Calculated Reflected differences											
Carriageway / Kerb	48.0	72.0	107.0	46.0	175.0	47.0	195.0	59.0	112.0	156.0	52.0
Kerb / Footway	80.0	154.0	125.0	14.0	81.0	40.0	414.0	135.0	71.0	42.0	136.0
Carriageway/Footway	32.0	226.0	232.0	32.0	94.0	7.0	609.0	194.0	183.0	198.0	188.0
Decibel - 1 minute											
Db reading Max	66.1	72.0	70.0	71.1	68.7	77.3	79.4	72.0	74.5	74.3	79.4
Db reading Min	47.3	51.4	52.7	44.5	60.5	55.4	54.2	59.2	56.4	69.3	63.0

B.3 Day 3 Survey Data

B.3.1 Location, Visual, Dimension and Incline data

Metric Measured	Piershill	Morningside Church Hill Theatre	Greenhill Place	Simpsons Loan	Alva Street
General	Day 3 Survey Results				
Date	21/02/2022	21/02/2022	21/02/2022	21/02/2022	21/02/2022
Time					
Location data					
Weather conditions	Sunny, wet	Sunny, wet	Sunny, wet	Overcast, dry	Overcast, dry
Coordinates					
OS National Grid	NT 28430 74168	NT 24506 71727	NT 24541 71802	NT 25402 72895	NT 24467 73652
Latitude / Longitude	55.955786 N 03.147786 W	55.932660 N 03.210020 W	55.933343 N 03.209395 W	55.943295 N 03.195915 W	55.949944 N 03.211089 W
Speed Limit / Traffic Restrictions	30mph Bus Lane	20mph Bus stop nearby	20mph Private Accesses	20mph Speed bumps Zebra crossing	20mph One way
Kerbside parking	Taxi Rank only	Yes	Yes	No	Yes
Loading / Unloading	Yes	Loading only	No	No	No
Visual data					
Carriageway material	Ashphalt w/ black chips	Ashphalt	Ashphalt	Ashphalt w/ black chips	Ashphalt
Kerb material	Concrete	Stone	Stone	Stone	Stone
Kerb shape	Chamfer	Square-nosed	Square-nosed U-shaped gully	Square-nosed	Square-nosed
Footway material	Ashphalt w/ white chips	Concrete slabs	Ashphalt w/ red + black chips	Stone slabs	Stone slabs
Cycleway material	Ashphalt w/ red chips	N / A	N / A	N / A	N / A
Kerb measurements					
Width (mm)	Top: 120.0 Chamfer: 40.0	140.0	95.0	255.0	152.0
Height (mm)	85.0	92.0	105.0	100.0	90.0
Incline (Degrees)					
Crossfall					
Footway	0.1	2.6	0.6	1.8	1.6
Carriageway	0.3	1.9	2.2	2.8	0.3
Longfall					
Footway	0.3	0.3	0.3	1.2	1.1
Carriageway	0.8	0.5	1	0.5	0.3
Crossing Complexity Rating	1	7	2	1	3

B.3.2 Luminance and Noise data

Metric Measured	Piershill	Morningside Church Hill Theatre	Greenhill Place	Simpsons Loan	Alva Street
General	**Day 3 Survey Results**				
Date	21/02/2022	21/02/2022	21/02/2022	21/02/2022	21/02/2022
Time					
Luminance					
Lux (40k) Max	33.7	15.5	19.2	2.4	2.1
	3373.0	1553.0	1915.0	235.0	210.0
Lux (40k) Min	31.1	13.8	15.6	2.3	2.1
	3110.0	1383.0	1557.0	227.0	206.0
Reflectied @ 100mm (4k) Max					
Carriageway	463.0	1070.0	369.0	121.0	122.0
Kerb	840.0	1058.0	564.0	298.0	152.0
Footway	386.0	1236.0	335.0	281.0	172.0
Bave	3241.5	1468.0	1736.0	231.0	208.0
Contrast					
Contrast - Carriageway	-0.9	-0.3	-0.8	-0.5	-0.4
Contrast - Kerb	-0.7	-0.3	-0.7	0.3	-0.3
Contrast - Footway	-0.9	-0.2	-0.8	0.2	-0.2
Real Contrast					
Carriageway / Kerb	-0.1	0.0	-0.1	-1.6	-0.3
Kerb / Footway	-0.2	0.8	-0.2	0.3	0.6
Calculated Reflected differences					
Carriageway / Kerb	377.0	12.0	195.0	177.0	30.0
Kerb / Footway	454.0	178.0	229.0	17.0	20.0
Carriageway/Footway	77.0	166.0	34.0	160.0	50.0
Decibel - 1 minute					
Db reading Max	77.6	82.1	58.5	72.2	66.3
Db reading Min	59.2	70.8	47.9	54.6	52.7

C. Kerb data analysis

C.1 Kerb height by setting

Kerb Heights	Average of Height (mm)	Min of Height (mm)	Max of Height (mm)
City centre	**83**	**55**	**125**
Main street	**90**	**55**	**125**
Commercial or mixed development (pre - 2010)	85	85	85
New build commercial or mixed development (post - 2010)	100	100	100
On street retail (pre-2010)	90	55	125
Side street	**76**	**55**	**90**
Commercial or mixed development (pre - 2010)	80	80	80
New build commercial or mixed development (post - 2010)	55	55	55
On street retail (pre-2010)	78	75	80
Residential (Pre-2010)	90	90	90
Urban	**81**	**40**	**110**
Main street	**78**	**40**	**110**
Commercial or mixed development (pre - 2010)	85	85	85
New build commercial or mixed development (post - 2010)	75	40	110
Side street	**83**	**60**	**105**
Commercial or mixed development (pre - 2010)	105	105	105
New build commercial or mixed development (post - 2010)	100	100	100
New residential development (post 2010)	60	60	60
Residential (Pre-2010)	65	65	65
Old Town	**104**	**70**	**140**
Main street	**116**	**85**	**140**
Commercial or mixed development (pre - 2010)	140	140	140
New build commercial or mixed development (post - 2010)	124	124	124
On street retail (pre-2010)	85	85	85
Side street	**96**	**70**	**113**
Commercial or mixed development (pre - 2010)	95	95	95

Kerb Heights	Average of Height (mm)	Min of Height (mm)	Max of Height (mm)
New build commercial or mixed development (post - 2010)	113	113	113
On street retail (pre-2010)	104	104	104
Residential (Pre-2010)	70	70	70
Suburban	**99**	**92**	**105**
Main street	**92**	**92**	**92**
Commercial or mixed development (pre - 2010)	92	92	92
Side street	**105**	**105**	**105**
Residential (Pre-2010)	105	105	105

C.2 Gradients by setting

C.2.1 Crossfall

Crossfall	Footway			Carriageway		
	Average F/way	Min F/way	Max F/way	Average C/way	Min C/way	Max C/way
Commercial or mixed development (pre - 2010)	**1.5**	**0.1**	**2.6**	**2.4**	**0.3**	**7.6**
City centre	**0.9**	**0.7**	**1.1**	**4.4**	**0.4**	**7.6**
Main street	1.0	0.8	1.1	2.9	0.4	5.3
Side street	0.7	0.7	0.7	7.6	7.6	7.6
Urban	**1.2**	**0.1**	**2.3**	**0.4**	**0.3**	**0.5**
Main street	0.1	0.1	0.1	0.3	0.3	0.3
Side street	2.3	2.3	2.3	0.5	0.5	0.5
Old Town	**2.1**	**2**	**2.2**	**1.4**	**0.4**	**2.4**
Main street	2.0	2	2	0.4	0.4	0.4
Side street	2.2	2.2	2.2	2.4	2.4	2.4
Suburban	**2.6**	**2.6**	**2.6**	**1.9**	**1.9**	**1.9**
Main street	2.6	2.6	2.6	1.9	1.9	1.9
New build commercial or mixed development (post - 2010)	**1.7**	**0.8**	**2.9**	**1.2**	**0.5**	**2.8**
City centre	**1.4**	**0.8**	**1.9**	**1.1**	**0.8**	**1.3**
Main street	0.8	0.8	0.8	1.3	1.3	1.3
Side street	1.9	1.9	1.9	0.8	0.8	0.8
Urban	**1.8**	**1.2**	**2.5**	**1.4**	**0.6**	**2.8**
Main street	1.9	1.2	2.5	0.7	0.6	0.7
Side street	1.8	1.8	1.8	2.8	2.8	2.8
Old Town	**1.9**	**0.8**	**2.9**	**1.0**	**0.5**	**1.4**
Main street	0.8	0.8	0.8	0.5	0.5	0.5
Side street	2.9	2.9	2.9	1.4	1.4	1.4
New residential development (post 2010)	**2.3**	**2.3**	**2.3**	**2.0**	**2**	**2**
Urban	**2.3**	**2.3**	**2.3**	**2.0**	**2**	**2**
Side street	2.3	2.3	2.3	2.0	2	2
On street retail (pre-2010)	**1.6**	**0.3**	**3.5**	**2.2**	**0.3**	**3.9**
City centre	**1.7**	**0.3**	**3.5**	**2.3**	**0.3**	**3.9**
Main street	2.3	1.1	3.5	2.5	1.1	3.8
Side street	1.1	0.3	1.8	2.1	0.3	3.9
Old Town	**1.4**	**1.3**	**1.4**	**2.1**	**0.7**	**3.4**
Main street	1.3	1.3	1.3	0.7	0.7	0.7
Side street	1.4	1.4	1.4	3.4	3.4	3.4
Residential (Pre-2010)	**2.2**	**0.6**	**4.6**	**2.4**	**0.3**	**4.3**
City centre	**1.6**	**1.6**	**1.6**	**0.3**	**0.3**	**0.3**
Side street	1.6	1.6	1.6	0.3	0.3	0.3
Urban	**2.0**	**2**	**2**	**2.9**	**2.9**	**2.9**
Side street	2.0	2	2	2.9	2.9	2.9

Crossfall	Footway			Carriageway		
	Average F/way	Min F/way	Max F/way	Average C/way	Min C/way	Max C/way
Old Town	**4.6**	**4.6**	**4.6**	**4.3**	**4.3**	**4.3**
Side street	4.6	4.6	4.6	4.3	4.3	4.3
Suburban	**0.6**	**0.6**	**0.6**	**2.2**	**2.2**	**2.2**
Side street	0.6	0.6	0.6	2.2	2.2	2.2

C.2.2 Longitudinal

Longitudinal	Footway			Carriageway		
	Average F/way	Min F/way	Max F/way	Average C/way	Min C/way	Max C/way
Commercial or mixed development (pre - 2010)	**2.1**	**0.3**	**6.9**	**2.1**	**0.4**	**6.5**
City centre	**1.8**	**0.5**	**4.4**	**2.0**	**0.5**	**4.7**
Main street	2.5	0.6	4.4	2.7	0.7	4.7
Side street	0.5	0.5	0.5	0.5	0.5	0.5
Urban	**0.3**	**0.3**	**0.3**	**0.6**	**0.4**	**0.8**
Main street	0.3	0.3	0.3	0.8	0.8	0.8
Side street	0.3	0.3	0.3	0.4	0.4	0.4
Old Town	**5.4**	**3.8**	**6.9**	**4.6**	**2.7**	**6.5**
Main street	3.8	3.8	3.8	2.7	2.7	2.7
Side street	6.9	6.9	6.9	6.5	6.5	6.5
Suburban	**0.3**	**0.3**	**0.3**	**0.5**	**0.5**	**0.5**
Main street	0.3	0.3	0.3	0.5	0.5	0.5
New build commercial or mixed development (post - 2010)	**2.1**	**0**	**5.4**	**2.5**	**0.4**	**7.6**
City centre	**4.6**	**3.8**	**5.4**	**6.3**	**5.0**	**7.6**
Main street	3.8	3.8	3.8	7.6	7.6	7.6
Side street	5.4	5.4	5.4	5.0	5.0	5.0
Urban	**0.7**	**0**	**1.2**	**1.2**	**0.5**	**2.3**
Main street	0.4	0	0.8	1.6	0.8	2.3
Side street	1.2	1.2	1.2	0.5	0.5	0.5
Old Town	**1.6**	**0.5**	**2.7**	**0.6**	**0.4**	**0.8**
Main street	0.5	0.5	0.5	0.4	0.4	0.4
Side street	2.7	2.7	2.7	0.8	0.8	0.8
New residential development (post 2010)	**0.7**	**0.7**	**0.7**	**3.2**	**3.2**	**3.2**
Urban	**0.7**	**0.7**	**0.7**	**3.2**	**3.2**	**3.2**
Side street	0.7	0.7	0.7	3.2	3.2	3.2
On street retail (pre-2010)	**2.7**	**0**	**7.7**	**2.8**	**0.2**	**7.9**
City centre	**1.6**	**0**	**3.7**	**1.8**	**0.2**	**2.9**
Main street	1.4	0.2	2.6	2.0	1.1	2.8
Side street	1.9	0	3.7	1.6	0.2	2.9

Longitudinal	Footway			Carriageway		
	Average F/way	Min F/way	Max F/way	Average C/way	Min C/way	Max C/way
Old Town	**4.9**	**2**	**7.7**	**4.9**	**1.8**	**7.9**
Main street	2.0	2	2.0	1.8	1.8	1.8
Side street	7.7	7.7	7.7	7.9	7.9	7.9
Residential (Pre-2010)	**1.2**	**0.3**	**2.8**	**2.7**	**0.3**	**8.6**
City centre	**1.1**	**1.1**	**1.1**	**0.3**	**0.3**	**0.3**
Side street	1.1	1.1	1.1	0.3	0.3	0.3
Urban	**0.7**	**0.7**	**0.7**	**0.8**	**0.8**	**0.8**
Side street	0.7	0.7	0.7	0.8	0.8	0.8
Old Town	**2.8**	**2.8**	**2.8**	**8.6**	**8.6**	**8.6**
Side street	2.8	2.8	2.8	8.6	8.6	8.6
Suburban	**0.3**	**0.3**	**0.3**	**1.0**	**1.0**	**1.0**
Side street	0.3	0.3	0.3	1.0	1.0	1.0

C.3 Contrast equation and analysis methods

Utilising the method conducted by Piotr Tomczuk et.al (Piotr Tomczuk, 2022) the portion of the light reflect was determined using Equation 1 below. Once the actual reflective values were known, the same equation was used to establish the relative contrast of the kerb against the background of both the footway and then the carriageway.

$$C = \frac{L_{Tmax} - L_{Bave}}{L_{Bave}}$$

Equation 1: Contrast

Where:

C = Contrast

L_{Tmax} = Maximum light reflected from surface

L_{Bave} = Average background / ambient light

When these values were used to find the contrast of the kerb the two negatives in the first line of the equation produced a positive. A negative score means the kerb is brighter than the background footway or carriageway and a positive means it is darker.

C.4 Contrast by setting

Contract by Setting	Kerb / Carriageway			Kerb Footway		
	Average	Min	Max	Average	Min	Max
Commercial or mixed development (pre - 2010)	**-0.50**	**-3.86**	**0.74**	**0.66**	**-0.74**	**3.55**
City centre	**-1.23**	**-3.86**	**0.74**	**0.77**	**-0.74**	**3.55**
Main street	-2.21	-3.86	-0.55	1.40	-0.74	3.55
Side street	0.74	0.74	0.74	-0.49	-0.49	-0.49
Urban	**-0.26**	**-0.38**	**-0.14**	**1.17**	**-0.16**	**2.50**
Main street	-0.14	-0.14	-0.14	-0.16	-0.16	-0.16
Side street	-0.38	-0.38	-0.38	2.50	2.50	2.50
Old Town	**0.08**	**0.01**	**0.16**	**-0.08**	**-0.08**	**-0.08**
Main street	0.16	0.16	0.16	-0.08	-0.08	-0.08
Side street	0.01	0.01	0.01	-0.08	-0.08	-0.08
Suburban	**0.03**	**0.03**	**0.03**	**0.77**	**0.77**	**0.77**
Main street	0.03	0.03	0.03	0.77	0.77	0.77
New build commercial or mixed development (post - 2010)	**-0.79**	**-3.80**	**0.73**	**0.23**	**-1.13**	**1.69**
City centre	**0.32**	**-0.10**	**0.73**	**0.35**	**0.09**	**0.61**
Main street	-0.10	-0.10	-0.10	0.09	0.09	0.09
Side street	0.73	0.73	0.73	0.61	0.61	0.61
Urban	**-2.07**	**-3.80**	**-0.80**	**0.30**	**-1.13**	**1.69**
Main street	-2.30	-3.80	-0.80	0.28	-1.13	1.69
Side street	-1.61	-1.61	-1.61	0.34	0.34	0.34
Old Town	**0.03**	**0.01**	**0.04**	**0.00**	**-0.08**	**0.08**
Main street	0.04	0.04	0.04	0.08	0.08	0.08
Side street	0.01	0.01	0.01	-0.08	-0.08	-0.08
New residential development (post 2010)	**-0.19**	**-0.19**	**-0.19**	**-0.07**	**-0.07**	**-0.07**
Urban	**-0.19**	**-0.19**	**-0.19**	**-0.07**	**-0.07**	**-0.07**
Side street	-0.19	-0.19	-0.19	-0.07	-0.07	-0.07
On street retail (pre-2010)	**-0.34**	**-0.90**	**0.09**	**-1.08**	**-2.99**	**0.24**
City centre	**-0.39**	**-0.90**	**-0.14**	**-1.13**	**-2.99**	**0.24**
Main street	-0.25	-0.36	-0.14	-1.37	-2.99	0.24
Side street	-0.53	-0.90	-0.16	-0.89	-1.65	-0.14
Old Town	**-0.23**	**-0.55**	**0.09**	**-0.98**	**-1.87**	**-0.09**
Main street	0.09	0.09	0.09	-0.09	-0.09	-0.09
Side street	-0.55	-0.55	-0.55	-1.87	-1.87	-1.87
Residential (Pre-2010)	**-0.15**	**-0.35**	**0.06**	**-0.06**	**-0.36**	**0.56**
City centre	**-0.35**	**-0.35**	**-0.35**	**0.56**	**0.56**	**0.56**
Side street	-0.35	-0.35	-0.35	0.56	0.56	0.56
Urban	**-0.18**	**-0.18**	**-0.18**	**-0.27**	**-0.27**	**-0.27**
Side street	-0.18	-0.18	-0.18	-0.27	-0.27	-0.27
Old Town	**0.06**	**0.06**	**0.06**	**-0.36**	**-0.36**	**-0.36**
Side street	0.06	0.06	0.06	-0.36	-0.36	-0.36

Contract by Setting	Kerb / Carriageway			Kerb Footway		
	Average	Min	Max	Average	Min	Max
Suburban	**-0.14**	**-0.14**	**-0.14**	**-0.16**	**-0.16**	**-0.16**
Side street	-0.14	-0.14	-0.14	-0.16	-0.16	-0.16

C.5 Decibel by setting

Decibels by Setting	Db Max	Db Min	Average Db
Commercial or mixed development (pre - 2010)	**82.1**	**52.7**	**66.98**
City centre	**79.4**	**54.2**	**65.95**
Main street	79.4	54.2	66.13
Side street	72	59.2	65.60
Urban	**77.6**	**52.7**	**64.88**
Main street	77.6	59.2	68.40
Side street	70	52.7	61.35
Old Town	**77.1**	**58.9**	**65.90**
Main street	77.1	63.3	70.20
Side street	64.3	58.9	61.60
Suburban	**82.1**	**70.8**	**76.45**
Main street	82.1	70.8	76.45
New build commercial or mixed development (post - 2010)	**78**	**51.4**	**65.84**
City centre	**76.3**	**57.4**	**65.23**
Main street	76.3	58.9	67.60
Side street	68.3	57.4	62.85
Urban	**72.2**	**51.4**	**63.23**
Main street	72	51.4	63.15
Side street	72.2	54.6	63.40
Old Town	**78**	**65.8**	**70.38**
Main street	70.2	65.8	68.00
Side street	78	67.5	72.75
New residential development (post 2010)	**71.1**	**44.5**	**57.80**
Urban	**71.1**	**44.5**	**57.80**
Side street	71.1	44.5	57.80
On street retail (pre-2010)	**79.4**	**55.4**	**68.85**
City centre	**79.4**	**55.4**	**69.34**
Main street	79.4	62	69.60
Side street	77.3	55.4	69.08
Old Town	**78.4**	**57.7**	**67.88**
Main street	73.4	62	67.70
Side street	78.4	57.7	68.05
Residential (Pre-2010)	**73.4**	**47.3**	**59.28**
City centre	**66.3**	**52.7**	**59.50**
Side street	66.3	52.7	59.50
Urban	**66.1**	**47.3**	**56.70**
Side street	66.1	47.3	56.70
Old Town	**73.4**	**62**	**67.70**
Side street	73.4	62	67.70

Decibels by Setting	Db Max	Db Min	Average Db
Suburban	**58.5**	**47.9**	**53.20**
Side street	58.5	47.9	53.20

D. Understanding participants

D.1.1 Ethical Procedure

The Standard Edinburgh Napier Ethical procedure was followed (Research Integrity, 2022) including informed consent, permission for recording, and right for withdrawal. Data was managed using the ENU compliancy rules for the UK Data Protection Act 2018 (GDPR) and associated legislation in vigour in the United Kingdom, with anonymity and security of storage.

D.1.2 Common classifications of the functional areas

- Medical
- Loss of Central Vision
- Loss of Peripheral (side) Vision
- Blurred Vision
- Generalised Haze
- Extreme Light Sensitivity
- Night Blindness
- Social
- UK designated Full disability
- UK designated Partial disability

Tables in appendix F provide practical descriptions of the different levels of ability in the main categories taken from the Office of National Statistics (ONS).

The following list is commonly accepted vision impairment conditions listed in 2. Medical above along with brief descriptions of each impairment:

D.1.2.1 Visual

- Loss of Central Vision – Creates a blur/blind spot but peripheral vision remains intact. This results in difficulty in reading, recognising faces and distinguishing details at distance. Mobility usually unaffected.
- Loss of Peripheral (side) Vision – Inability to distinguish anything to one or either side of anything directly above and/or below eye level. Central vision remains unaffected making it possible to see directly ahead. Can affect mobility and can slow reading speed in more severe cases. Typically referred as ‘tunnel vision’.
- Blurred Vision – Objects near and far appear out of focus
- Generalised Haze – Causes a sensation of a film or glare potentially over the entire field of view

- Extreme Light Sensitivity – Standard levels of illumination overwhelm the visual systems causing a washed-out image and/or glare disability. Can cause pain or comfort from levels of illumination considered normal.
- Night Blindness – Results in inability to see outside at night-time underneath star or moon light and potentially in dimly lit interiors such as movie theatres or restaurants

D.1.2.2 Hearing

Hearing loss and deafness happen when sound signals don't reach the brain. This is caused by a problem in the hearing system.

There are two main types of hearing loss. It's possible to have both types, and this is known as mixed hearing loss.

Sensorineural hearing loss

This is caused by damage to the hair cells inside the inner ear, or damage to the hearing nerve, or both. It makes it more difficult to hear quiet sounds and reduces the quality of sound that you can hear. Sensorineural hearing loss is permanent but can often be treated with hearing aids.

Conductive hearing loss

This happens when a blockage, such as ear wax, stops sound passing from your outer ear to your inner ear. Sounds will become quieter, and things might sound muffled. It can be temporary or permanent. Conductive hearing loss is usually caused by ear problems.

Age-related hearing loss

Age-related damage to the inner ear is the single biggest cause of hearing loss. It's also known as presbycusis. Most of us will experience some level of hearing loss as we get older. This type of hearing loss tends to affect both ears and increases as you get older.

Causes of age-related hearing loss

The main cause of age-related hearing loss is gradual wear and tear to tiny sensory cells called 'hair cells' in the cochlea (your hearing organ in the inner ear). There is no cure for age-related hearing loss, but many people find hearing aids to be a huge help.

https://rnid.org.uk/information-and-support/hearing-loss/

D.1.2.3 Physical Movement

Physical movement difficulties encompass physical disabilities and movement disorders (neurological). It is also related to System category, meaning any condition that affects the whole system that affects movement as an overall effect, for example, heart disease, asthma etc.

Movement disorders are neurologic conditions that cause problems with movement, such as:

- Increased movement that can be voluntary (intentional) or involuntary (unintended). Decreased or slow voluntary movement. There are many different movement disorders. Some of the more common types include:
  - Ataxia, the loss of muscle coordination
  - Dystonia, in which involuntary contractions of your muscles cause twisting and repetitive movements. The movements can be painful.
  - Huntington's disease, an inherited disease that causes nerve cells in certain parts of the brain to waste away. This includes the nerve cells that help to control voluntary movement.
  - Parkinson's disease, which is disorder that slowly gets worse over time. It causes tremors, slowness of movement, and trouble walking.
  - Tourette syndrome, a condition which causes people to make sudden twitches, movements, or sounds (tics)
  - Tremor and essential tremor, which cause involuntary trembling or shaking movements. The movements may be in one or more parts of your body.
- Causes of movement disorders include:
  - Genetics
  - Infections
  - Medicines
  - Damage to the brain, spinal cord, or peripheral nerves
  - Metabolic disorders
  - Stroke and vascular diseases
  - Toxins

Some movement disorders, such as hiccups, are temporary, usually causing little inconvenience. Others, such as Parkinson’s disease, are serious and progressive, impairing the ability to speak, use the hands, walk, and maintain balance when standing.

https://medlineplus.gov/movementdisorders.html

https://www.hopkinsmedicine.org/neurology_neurosurgery/centers_clinics/movement_disorders/conditions/

D.1.2.4 Thinking

Thinking is an operationalised category developed for the project.

It can encompass head injury, dementia, and mental illness. For the inclusive kerbs project, it primarily memory and sequences of action.

Cognitive disorders are a part of the neurocognitive disorder classification in the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-V). Cognitive disorders are defined as any disorder that significantly impairs the cognitive function of an individual to the point where normal functioning in society is impossible without treatment. Some common cognitive disorders include:

- Dementia
- Developmental disorders
- Motor skill disorders
- Amnesia
- Substance-induced cognitive impairment
- Alzheimer's disease

https://www.psychguides.com/neurological-disorders/cognitive/

D.1.2.5 Systemic (overall mobility)

A vast range of disabilities and conditions can result in mobility and physical difficulties, which may impact on your access to learning. Some of the most common ongoing or permanent conditions result from muscular and skeletal disabilities and from ongoing medical conditions which affect mobility. Some disabilities may be more 'seen' or evident than others.

Conditions that limit mobility include multiple sclerosis, Parkinson's disease, stroke, traumatic brain or spine injuries, congenital abnormalities, obesity, arthritis, lower limb ischemia, and lung and balance disorders. There has been limited research on the psychosocial effects and quality of life experienced by people with these conditions. In addition to limited mobility, symptoms of pain and fatigue are common and may have a negative effect on psychosocial and physical functioning. Strategies to improve coping with symptoms of mobility-limiting conditions may improve quality of life for these individuals.

Some examples of disabilities and conditions that can have an impact on mobility, fatigue and pain levels are:

- Back and neck problems
- Accidents or injury leading to long term disability
- Arthritis and any other condition affecting the joints
- Amputation
- Fibromyalgia
- Multiple sclerosis
- Partial or total paralysis
- Cerebral palsy
- Head injury

Some examples of disabilities and conditions that can have an impact on coordination, dexterity, strength, speed, and stamina are:

- Respiratory and cardiac diseases
- Epilepsy
- Diabetes
- Cancer
- AIDS

https://www.salford.ac.uk/askus/support/disability-and-learner-support/long-term-medical-conditions-mobility-and-physical

E. Difficulty categories

Table E.1- Full table of difficulty categories and descriptive for each relevant functional area Descriptions from Elliot et al., 1992.

E.1.1 Category A - Severe

	Description	ONS Level	ONS descriptive	Notes
Category A	**Severe**			
	Vision	0	Not required to perceive anything by sight	
	Recognition	1	Required to Recognise a friend at arm's length away	
	Hearing	0	Not required to perceive anything by hearing	
	Speech	1	Required to Understand loud speech in a quiet room	
	Sounds	1	Required to Follow a TV with the volume turned up	
	Physical Movement	1	Required to Walk 50 metres (≈ 50 yds) without stopping	Or less e.g., wheelchair
	Steps	1	Required to Manage 1 step	
	Balance	2	Required to Balance for short periods of time, without holding on to something	
	Thinking	0	Not Required to Do something without forgetting what the task was whilst in the middle of it	
	Sequence	0	Not Required to Hold a conversation without losing track of what is being said	
Not an ONS scale	Systemic	0	Not required to walk	
	Locomotion	0	Not required to bend down	
	Reach & stretch	1	Required to Reach one arm out in front (briefly)	Or less

E.1.2 Category B - Moderate

	Description	ONS Level	ONS descriptive	Notes
Category B	**Moderate**			
	Vision	2	Required to Read a large print book	
	Recognition	2	Required to Recognise a friend across the room,	
	Hearing			
	Speech	2	Required to Use an ordinary telephone	
	Sounds	2	Required to Hear a telephone bell	
	Physical Movement	2	Required to Walk 175 metres (≈ 200 yds) without stopping	
	Steps	2	Required to Manage 12 steps, using a handrail if necessary	
	Balance	2	Required to Balance for short periods of time, without holding on to something	
		1	Required to Bend down far enough to touch knees, and then straighten up again	

	Description	ONS Level	ONS descriptive	Notes
	Thinking	1	Required to Think clearly, without muddling thoughts	
	Sequence	1	Required to Do something without forgetting what the task was whilst in the middle of it	
		1	Required to Remember to turn things off, such as fires, cookers, or taps	
Not an ONS scale	Systemic	2	Required to Walk 175 metres (≈ 200 yds) without stopping	
	Dexterity	2	Required to Pick up and carry a pint of milk with either the left or right hand	
	Reach & stretch	1	Required to Reach one arm out in front (for long periods)	
	Bending	1	Required to Bend down far enough to touch knees, and then straighten up again	

E.1.3 Category C – Light to Moderate

	Description	ONS Level	ONS descriptive	Notes
Category C	**Light to moderate**			
	Vision	2	Required to Read a large print book	
		3	Required to Recognise a friend across the road	
	Hearing	2	Required to Use an ordinary telephone	
		3	Required to Follow a conversation against background noise	
	Physical movement	2	Required to Walk 175 metres (≈ 200 yds) without stopping	
		2	Required to Manage 12 steps, using a handrail if necessary	
		2	Required to Bend down to pick something up from the floor, and then straighten up again	
		2	Required to Balance for short periods of time, without holding on to something	
	Thinking	1	Required to Do something without forgetting what the task was whilst in the middle of it	
		1	Required to Hold a conversation without losing track of what is being said	
	Systemic	1	Required to Reach one arm out in front (for long periods)	
		2	Required to Bend down to pick something up from the floor, and then straighten up again	

E.1.4 Category D – No Difficulty Discernible

	Description	ONS Level	ONS descriptive	Notes
Category D	**No difficulty discernible**			
	Vision	3	Required to Read ordinary newsprint	
		3	Required to Recognise a friend across the road	
	Hearing	3	Required to Follow a conversation against background noise	
		3	Required to Follow a TV at a normal volume	
	Physical movement	3	Required to Kneel down (e.g., to use a dustpan and brush), and then straighten up again	

Description	ONS Level	ONS descriptive	Notes
	3	Required to Manage 12 steps, without using a handrail	
	3	Required to Balance for long periods of time, without holding on to something	
Thinking	1	Required to Think clearly, without muddling thoughts	
	1	Required to Watch a 30 min. TV programme, and tell someone what it was about	
Systemic	3	Required to Walk 350 metres (≈ 400 yds) without stopping	
	3	Required to Pick up and carry a bag of potatoes with either the left or right hand	

F. Sampling statistics

F.1 Difficulties by capability type

Capability	Vision	Stamina	Learning and Memory	Hearing	Mental Health, socially & behavioural	Mobility & Dexterity
Yes	218	675	333	243	497	929
No	1545	1088	1430	1520	1266	834
None	323	323	323	323	323	323
Total	**2086**	**2086**	**2086**	**2086**	**2086**	**2086**

F.2 Difficulties by age

This section presents the distribution of respondents who self-reported difficulties with each capability type by age group. Older adult respondents (age 65 and over) are presented to yield the highest proportions of self-reported difficulties across almost all capabilities considered in this study, with the exception of mental health, social & behavioural difficulties.

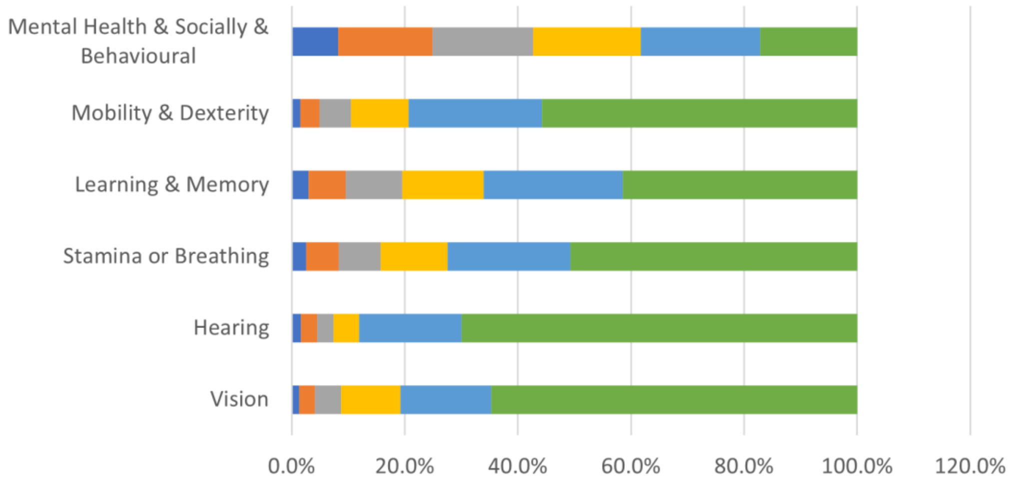
Difficulties with mental health, social & behavioural difficulties are shown to yield similar proportions across all age groups, apart from the youngest group (age 16 to 24).

Younger age groups (i.e., 16 to 24, 25 to 34, and 35 to 44) have lower proportions of difficulties across all capability types. Focusing on the oldest age group (age 65 and over), difficulties with hearing are encountered by 70% of the older adult respondents, difficulties with vision by 65%, with mobility and dexterity by approximately 56%, with stamina or breathing by about 51%, and with learning and memory by about 41%.

For respondents with age between 55 and 64 years, learning and memory as well as mobility and dexterity yield the highest proportions of difficulties (24.6% and 23.6%, respectively), whereas for respondents belonging in the 45-54 age range, difficulties with mental health, social & behavioural capabilities yield the highest proportion (about 19%) compared to other capability types.

It is also worthwhile to note that difficulties with hearing yield very low proportions (<5%) across all age groups up to 54 years, whereas for the oldest age group, difficulties with hearing were self-reported by 7 out of 10 respondents.

Figure F1: Distribution of respondents with difficulties by capability type and age group



	Vision	Hearing	Stamina or Breathing	Learning & Memory	Mobility & Dexterity	Mental Health & Socially & Behavioural
Age 16 to 24	1.4%	1.6%	2.5%	3.0%	1.5%	8.2%
Age 25 to 34	2.8%	2.9%	5.8%	6.6%	3.4%	16.7%
Age 35 to 44	4.6%	2.9%	7.4%	9.9%	5.5%	17.7%
Age 45 to 54	10.6%	4.5%	11.9%	14.4%	10.2%	19.1%
Age 55 to 64	16.1%	18.1%	21.8%	24.6%	23.6%	21.1%
Age 65 and over	64.7%	70.0%	50.7%	41.4%	55.8%	17.1%

Age 16 to 24 | Age 25 to 34 | Age 35 to 44 | Age 45 to 54 | Age 55 to 64 | Age 65 and over

F.2.1 Difficulty with vision

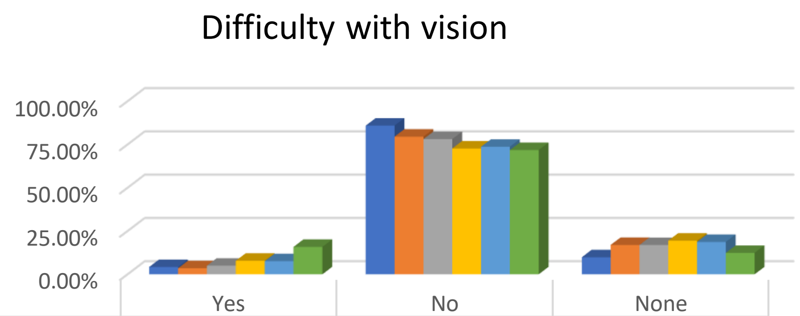
2a Frequency

Difficulty with vision	Yes	No	None	Total
Age 16 to 24	3	61	7	71
Age 25 to 34	6	136	29	171
Age 35 to 44	10	157	34	201
Age 45 to 54	23	213	57	293
Age 55 to 64	35	339	86	460
Age 65 and over	141	639	110	890

2b Percentage

Difficulty with vision	Yes	No	None	Total
Age 16 to 24	4.23%	85.92%	9.86%	100.00%
Age 25 to 34	3.51%	79.53%	16.96%	100.00%
Age 35 to 44	4.98%	78.11%	16.92%	100.00%
Age 45 to 54	7.85%	72.70%	19.45%	100.00%
Age 55 to 64	7.61%	73.70%	18.70%	100.00%
Age 65 and over	**15.84%**	**71.80%**	**12.36%**	**100.00%**

2c Chart



	Yes	No	None
Age 16 to 24	4.23%	85.92%	9.86%
Age 25 to 34	3.51%	79.53%	16.96%
Age 35 to 44	4.98%	78.11%	16.92%
Age 45 to 54	7.85%	72.70%	19.45%
Age 55 to 64	7.61%	73.70%	18.70%
Age 65 and over	15.84%	71.80%	12.36%

Age 16 to 24 Age 25 to 34 Age 35 to 44
Age 45 to 54 Age 55 to 64 Age 65 and over

F.2.2 Difficulty with hearing

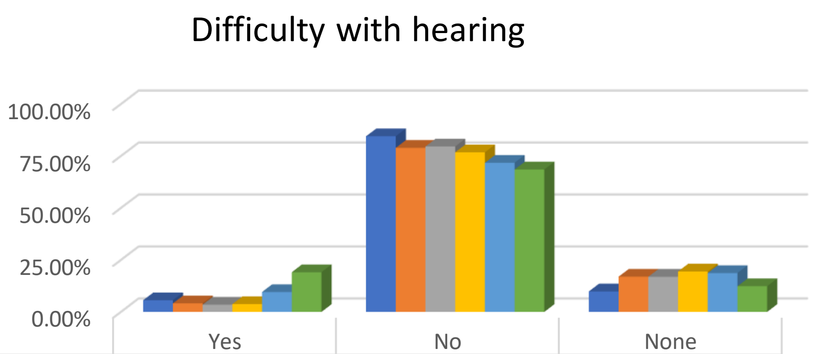
3a Frequency

Difficulty with hearing	Yes	No	None	Total
Age 16 to 24	4	60	7	71
Age 25 to 34	7	135	29	171
Age 35 to 44	7	160	34	201
Age 45 to 54	11	225	57	293
Age 55 to 64	44	330	86	460
Age 65 and over	170	610	110	890

3b Percentage

Difficulty with hearing	Yes	No	None	Total
Age 16 to 24	5.63%	84.51%	9.86%	100.00%
Age 25 to 34	4.09%	78.95%	16.96%	100.00%
Age 35 to 44	3.48%	79.60%	16.92%	100.00%
Age 45 to 54	3.75%	76.79%	19.45%	100.00%
Age 55 to 64	9.57%	71.74%	18.70%	100.00%
Age 65 and over	19.10%	68.54%	12.36%	100.00%

3c Chart



	Yes	No	None
Age 16 to 24	5.63%	84.51%	9.86%
Age 25 to 34	4.09%	78.95%	16.96%
Age 35 to 44	3.48%	79.60%	16.92%
Age 45 to 54	3.75%	76.79%	19.45%
Age 55 to 64	9.57%	71.74%	18.70%
Age 65 and over	19.10%	68.54%	12.36%

Age 16 to 24 Age 25 to 34 Age 35 to 44 Age 45 to 54 Age 55 to 64 Age 65 and over

F.2.3 Difficulty with mobility

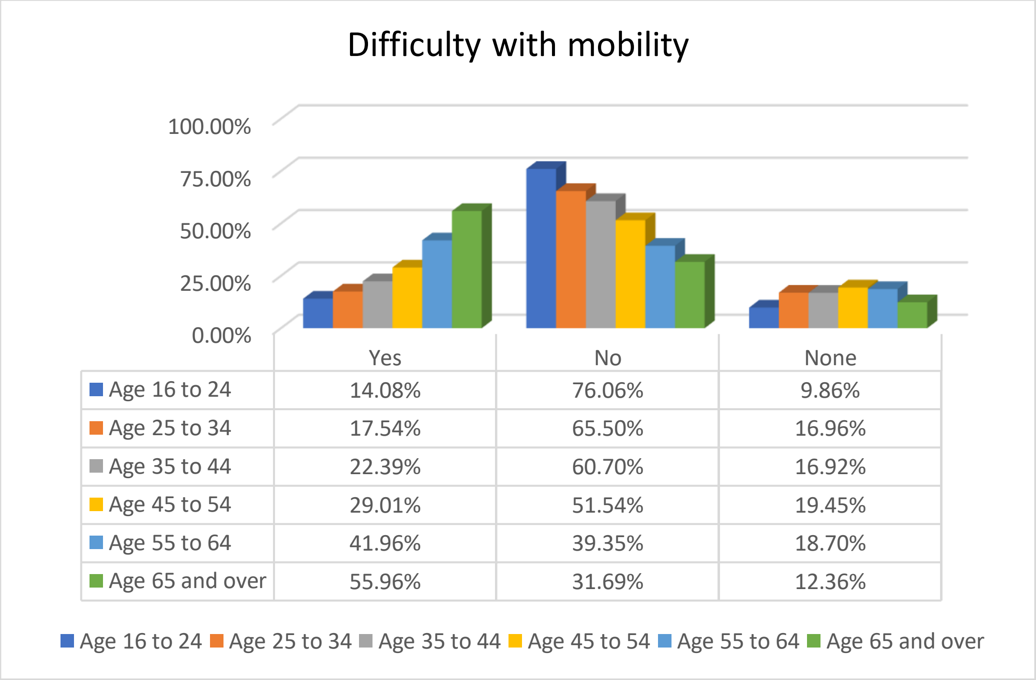
4a Frequency

Difficulty with mobility	Yes	No	None	Total
Age 16 to 24	10	54	7	71
Age 25 to 34	30	112	29	171
Age 35 to 44	45	122	34	201
Age 45 to 54	85	151	57	293
Age 55 to 64	193	181	86	460
Age 65 and over	498	282	110	890

4b Percentage

Difficulty with mobility	Yes	No	None	Total
Age 16 to 24	14.08%	76.06%	9.86%	100.00%
Age 25 to 34	17.54%	65.50%	16.96%	100.00%
Age 35 to 44	22.39%	60.70%	16.92%	100.00%
Age 45 to 54	29.01%	51.54%	19.45%	100.00%
Age 55 to 64	41.96%	39.35%	18.70%	100.00%
Age 65 and over	55.96%	31.69%	12.36%	100.00%

4c Chart



F.2.4 Difficulty with dexterity

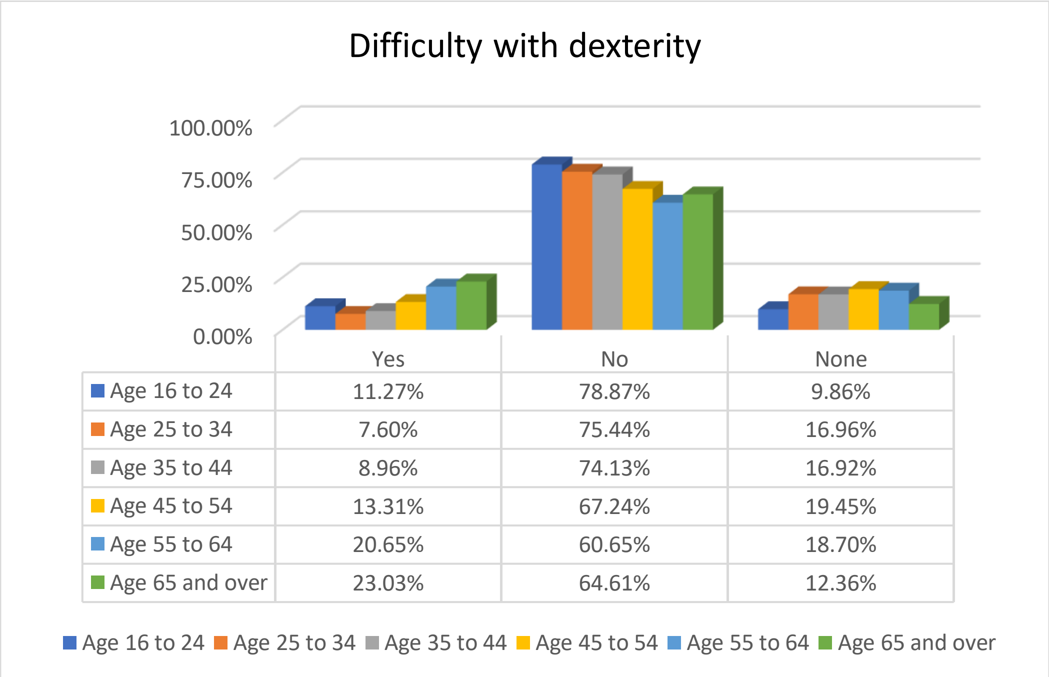
5a Frequency

Difficulty with mobility	Yes	No	None	Total
Age 16 to 24	8	56	7	71
Age 25 to 34	13	129	29	171
Age 35 to 44	18	149	34	201
Age 45 to 54	39	197	57	293
Age 55 to 64	95	279	86	460
Age 65 and over	205	575	110	890

5b Percentage

Difficulty with mobility	Yes	No	None	Total
Age 16 to 24	11.27%	78.87%	9.86%	100.00%
Age 25 to 34	7.60%	75.44%	16.96%	100.00%
Age 35 to 44	8.96%	74.13%	16.92%	100.00%
Age 45 to 54	13.31%	67.24%	19.45%	100.00%
Age 55 to 64	20.65%	60.65%	18.70%	100.00%
Age 65 and over	23.03%	64.61%	12.36%	100.00%

5c Chart



F.2.5 Difficulty with learning

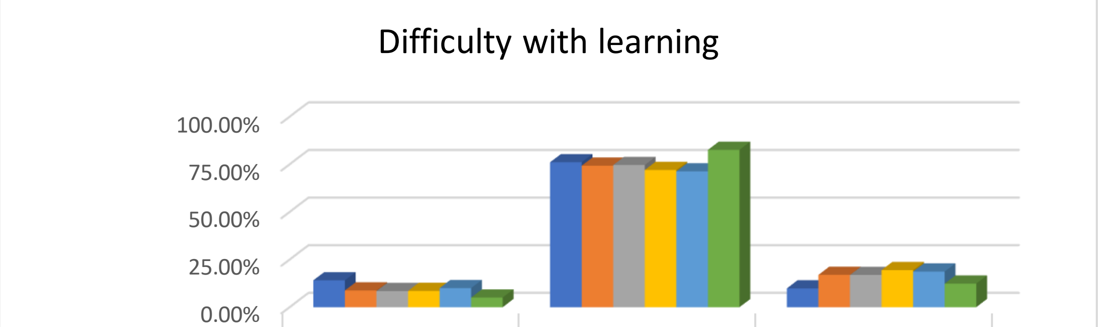
6a Frequency

Difficulty with learning	Yes	No	None	Total
Age 16 to 24	10	54	7	71
Age 25 to 34	15	127	29	171
Age 35 to 44	17	150	34	201
Age 45 to 54	25	211	57	293
Age 55 to 64	46	328	86	460
Age 65 and over	45	735	110	890

6b Percentage

Difficulty with learning	Yes	No	None	Total
Age 16 to 24	14.08%	76.06%	9.86%	100.00%
Age 25 to 34	8.77%	74.27%	16.96%	100.00%
Age 35 to 44	8.46%	74.63%	16.92%	100.00%
Age 45 to 54	8.53%	72.01%	19.45%	100.00%
Age 55 to 64	10.00%	71.30%	18.70%	100.00%
Age 65 and over	5.06%	82.58%	12.36%	100.00%

6c Chart



	Yes	No	None
Age 16 to 24	14.08%	76.06%	9.86%
Age 25 to 34	8.77%	74.27%	16.96%
Age 35 to 44	8.46%	74.63%	16.92%
Age 45 to 54	8.53%	72.01%	19.45%
Age 55 to 64	10.00%	71.30%	18.70%
Age 65 and over	5.06%	82.58%	12.36%

Age 16 to 24 Age 25 to 34 Age 35 to 44 Age 45 to 54 Age 55 to 64 Age 65 and over

F.2.6 Difficulty with memory

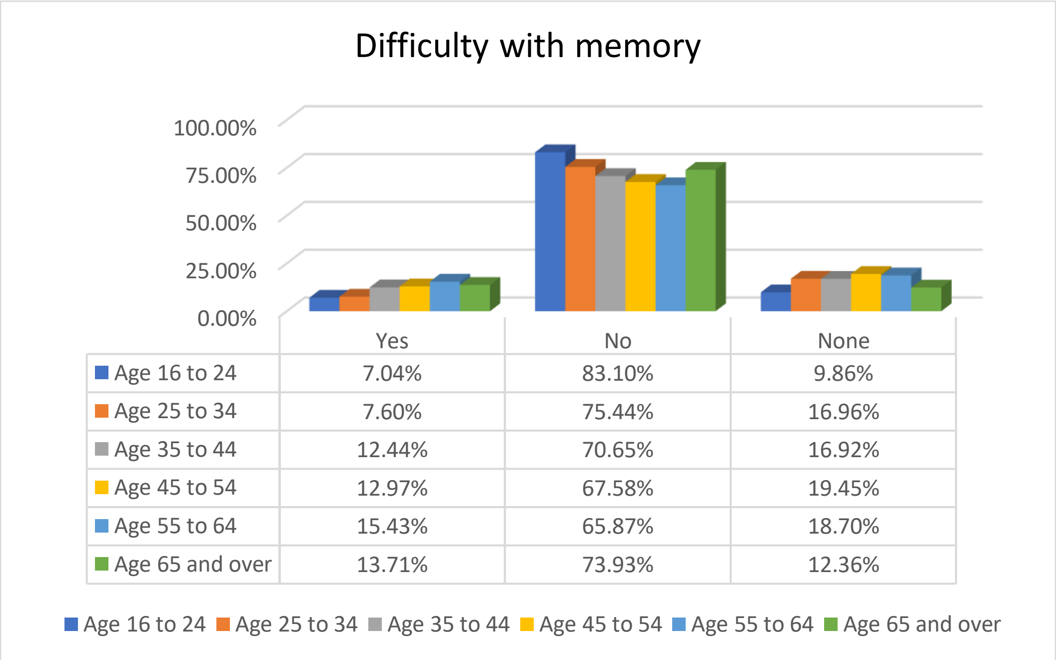
7a Frequency

Difficulty with memory	Yes	No	None	Total
Age 16 to 24	5	59	7	71
Age 25 to 34	13	129	29	171
Age 35 to 44	25	142	34	201
Age 45 to 54	38	198	57	293
Age 55 to 64	71	303	86	460
Age 65 and over	122	658	110	890

7b Percentage

Difficulty with memory	Yes	No	None	Total
Age 16 to 24	7.04%	83.10%	9.86%	100.00%
Age 25 to 34	7.60%	75.44%	16.96%	100.00%
Age 35 to 44	12.44%	70.65%	16.92%	100.00%
Age 45 to 54	12.97%	67.58%	19.45%	100.00%
Age 55 to 64	15.43%	65.87%	18.70%	100.00%
Age 65 and over	13.71%	73.93%	12.36%	100.00%

7c Chart



F.2.7 Difficulty with stamina or breathing

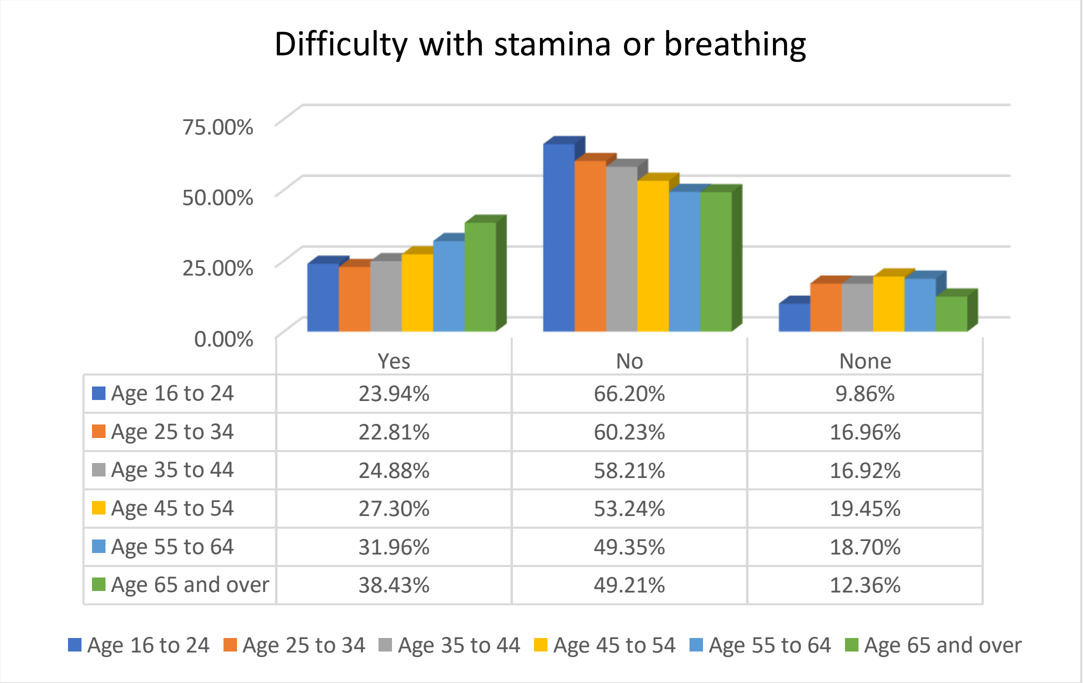
8a Frequency

Difficulty with stamina or breathing or	Yes	No	None	Total
Age 16 to 24	17	47	7	71
Age 25 to 34	39	103	29	171
Age 35 to 44	50	117	34	201
Age 45 to 54	80	156	57	293
Age 55 to 64	147	227	86	460
Age 65 and over	342	438	110	890

8b Percentage

Difficulty with stamina or breathing or	Yes	No	None	Total
Age 16 to 24	23.94%	66.20%	9.86%	100.00%
Age 25 to 34	22.81%	60.23%	16.96%	100.00%
Age 35 to 44	24.88%	58.21%	16.92%	100.00%
Age 45 to 54	27.30%	53.24%	19.45%	100.00%
Age 55 to 64	31.96%	49.35%	18.70%	100.00%
Age 65 and over	38.43%	49.21%	12.36%	100.00%

8c Chart



F.2.8 Day to day activities

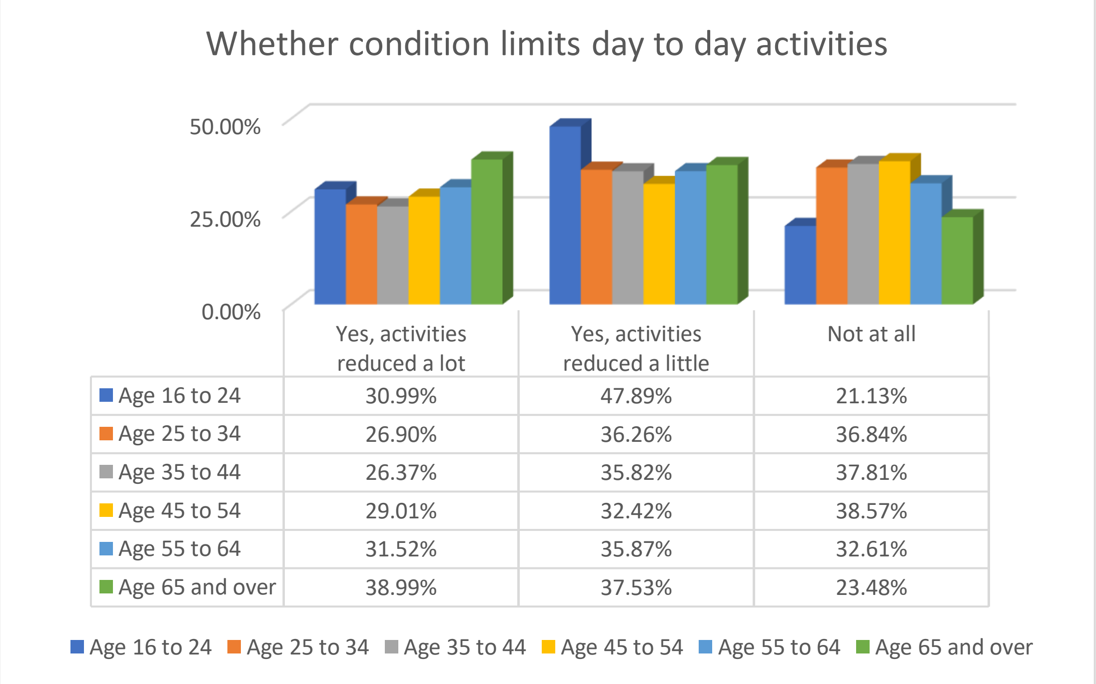
9a Frequency

Whether condition limits day to day activities	Yes, activities reduced a lot	Yes, activities reduced a little	Not at all	Total
Age 16 to 24	22	34	15	71
Age 25 to 34	46	62	63	171
Age 35 to 44	53	72	76	201
Age 45 to 54	85	95	113	293
Age 55 to 64	145	165	150	460
Age 65 and over	347	334	209	890

9b Percentage

Whether condition limits day to day activities	Yes, activities reduced a lot	Yes, activities reduced a little	Not at all	Total
Age 16 to 24	30.99%	47.89%	21.13%	100.00%
Age 25 to 34	26.90%	36.26%	36.84%	100.00%
Age 35 to 44	26.37%	35.82%	37.81%	100.00%
Age 45 to 54	29.01%	32.42%	38.57%	100.00%
Age 55 to 64	31.52%	35.87%	32.61%	100.00%
Age 65 and over	38.99%	37.53%	23.48%	100.00%

9c Chart



F.2.9 Progressive health condition

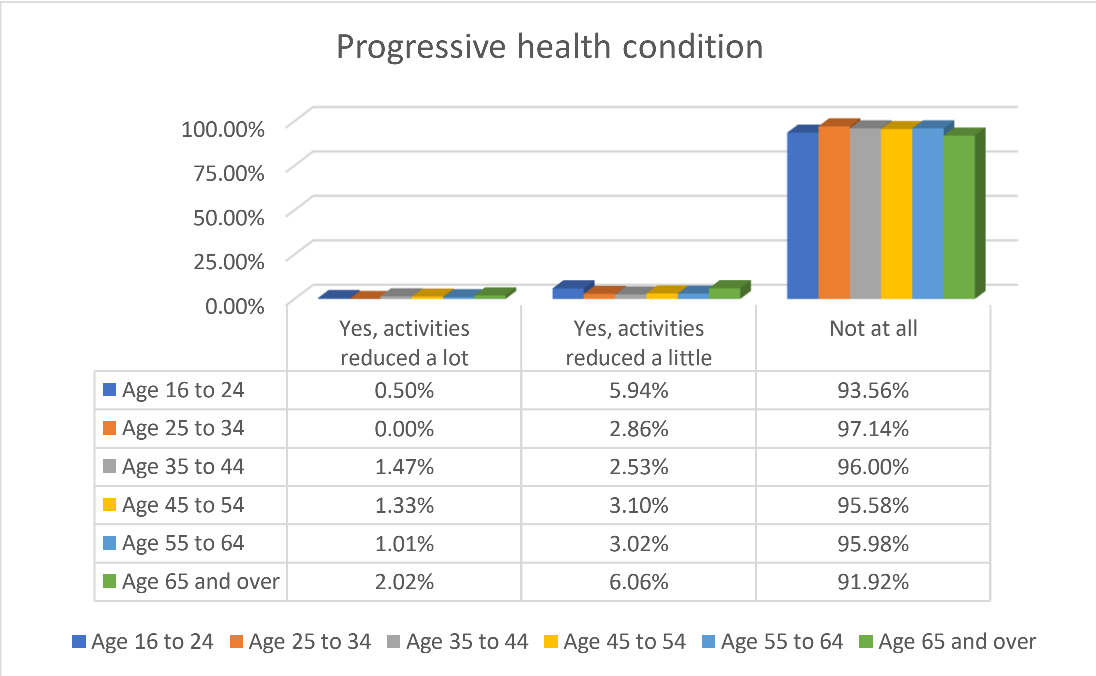
10a Frequency

Progressive health condition	Yes, activities reduced a lot	Yes, activities reduced a little	Not at all	Total
Age 16 to 24	1	12	189	202
Age 25 to 34		13	441	454
Age 35 to 44	7	12	456	475
Age 45 to 54	6	14	432	452
Age 55 to 64	5	15	477	497
Age 65 and over	12	36	546	594

10b Percentage

Progressive health condition	Yes, activities reduced a lot	Yes, activities reduced a little	Not at all	Total
Age 16 to 24	0.50%	5.94%	93.56%	100.00%
Age 25 to 34	0.00%	2.86%	97.14%	100.00%
Age 35 to 44	1.47%	2.53%	96.00%	100.00%
Age 45 to 54	1.33%	3.10%	95.58%	100.00%
Age 55 to 64	1.01%	3.02%	95.98%	100.00%
Age 65 and over	2.02%	6.06%	91.92%	100.00%

10c Chart



F.2.10 Illness / disability limited activities

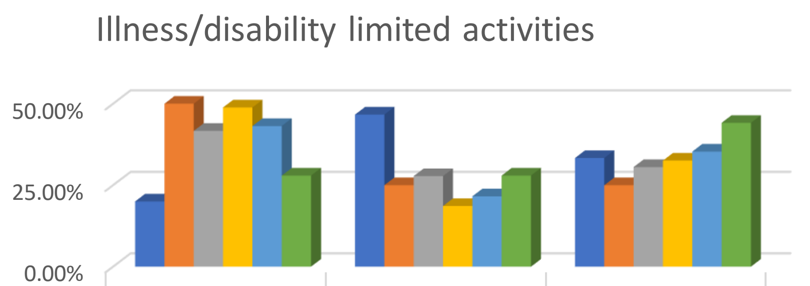
11a Frequency

Illness/disability limited activities	Yes, activities reduced a lot	Yes, activities reduced a little	Not at all	Total
Age 16 to 24	3	7	5	15
Age 25 to 34	12	6	6	24
Age 35 to 44	15	10	11	36
Age 45 to 54	21	8	14	43
Age 55 to 64	22	11	18	51
Age 65 and over	19	19	30	68

11b Percentage

Illness/disability limited activities	Yes, activities reduced a lot	Yes, activities reduced a little	Not at all	Total
Age 16 to 24	20.00%	46.67%	33.33%	100.00%
Age 25 to 34	50.00%	25.00%	25.00%	100.00%
Age 35 to 44	41.67%	27.78%	30.56%	100.00%
Age 45 to 54	48.84%	18.60%	32.56%	100.00%
Age 55 to 64	43.14%	21.57%	35.29%	100.00%
Age 65 and over	27.94%	27.94%	44.12%	100.00%

11c Chart

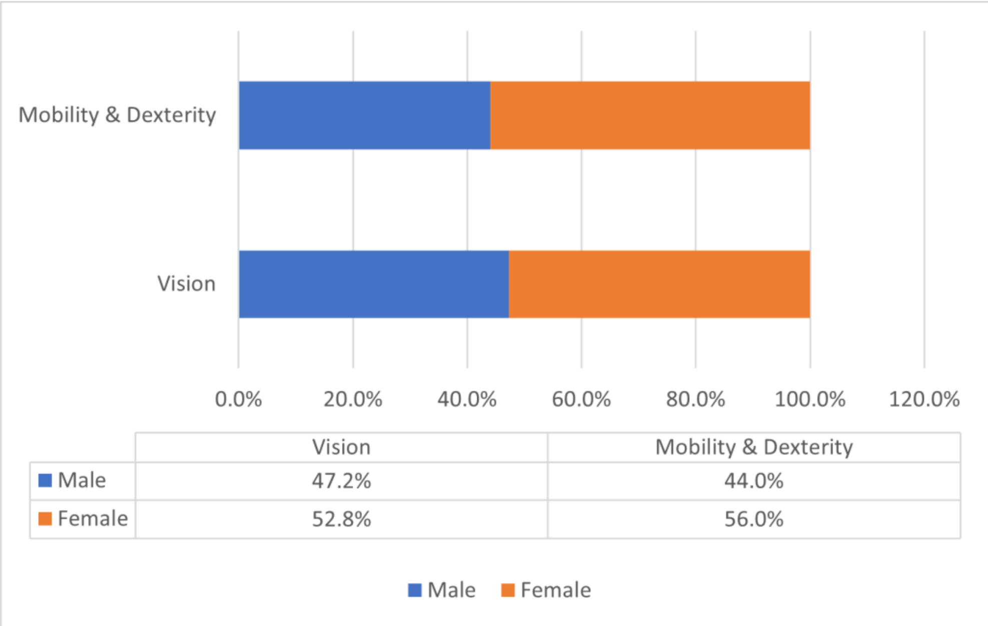


	Yes, activities reduced a lot	Yes, activities reduced a little	Not at all
Age 16 to 24	20.00%	46.67%	33.33%
Age 25 to 34	50.00%	25.00%	25.00%
Age 35 to 44	41.67%	27.78%	30.56%
Age 45 to 54	48.84%	18.60%	32.56%
Age 55 to 64	43.14%	21.57%	35.29%
Age 65 and over	27.94%	27.94%	44.12%

F.3 Difficulties by gender

Figure F2 indicates that there is a slight difference in the proportions of male and female respondents who self-reported difficulties with vision, and mobility and dexterity. For difficulties with vision, the male and female proportions are approximately equal to 47% and 53%, respectively. While for difficulties with mobility and dexterity, the male and female proportions stand at about 44% and 56% respectively.

Figure F2 Distribution of respondents having difficulties with vision and mobility & dexterity by gender



	Vision	Mobility & Dexterity
Male	47.2%	44.0%
Female	52.8%	56.0%

F.3.1 Difficulty with vision

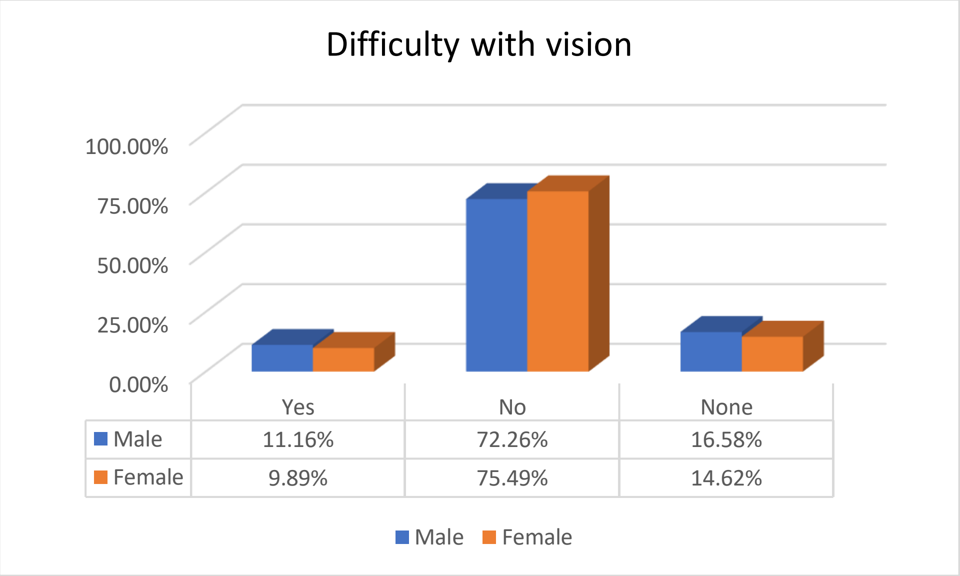
12a Frequency

Difficulty with vision	Yes	No	None	Total
Male	103	667	153	923
Female	115	878	170	1163

12b Percentage

Difficulty with vision	Yes	No	None	Total
Male	11.16%	72.26%	16.58%	100.00%
Female	9.89%	75.49%	14.62%	100.00%

12c Chart



F.3.2 Difficulty with mobility

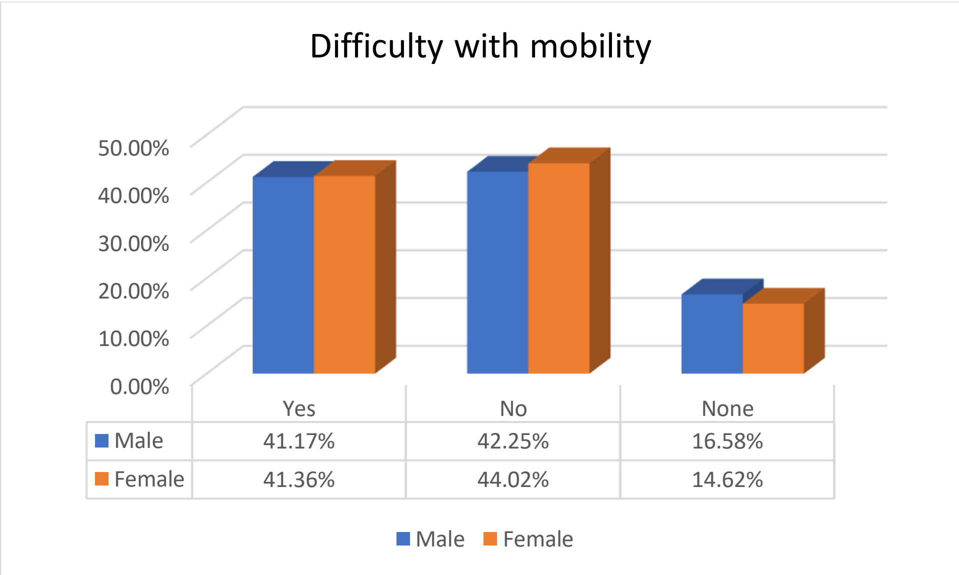
13a Frequency

Difficulty with mobility	Yes	No	None	Total
Male	380	390	153	923
Female	481	512	170	1163

13b Percentage

Difficulty with mobility	Yes	No	None	Total
Male	41.17%	42.25%	16.58%	100.00%
Female	41.36%	44.02%	14.62%	100.00%

13c Chart



F.3.3 Difficulty with learning

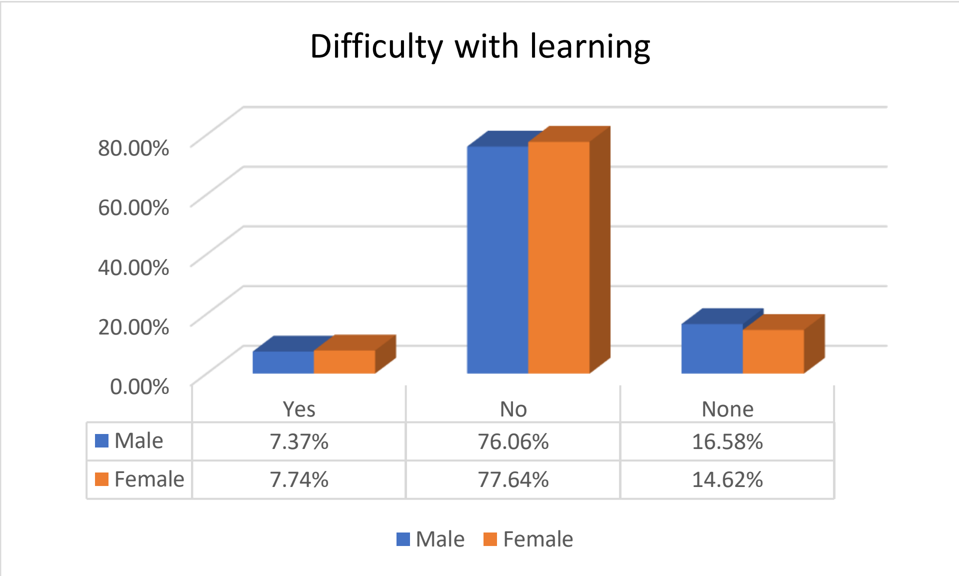
14a Frequency

Difficulty with learning	Yes	No	None	Total
Male	68	702	153	923
Female	90	903	170	1163

14b Percentage

Difficulty with learning	Yes	No	None	Total
Male	7.37%	76.06%	16.58%	100.00%
Female	7.74%	77.64%	14.62%	100.00%

14c Chart



F.3.4 Difficulty with memory

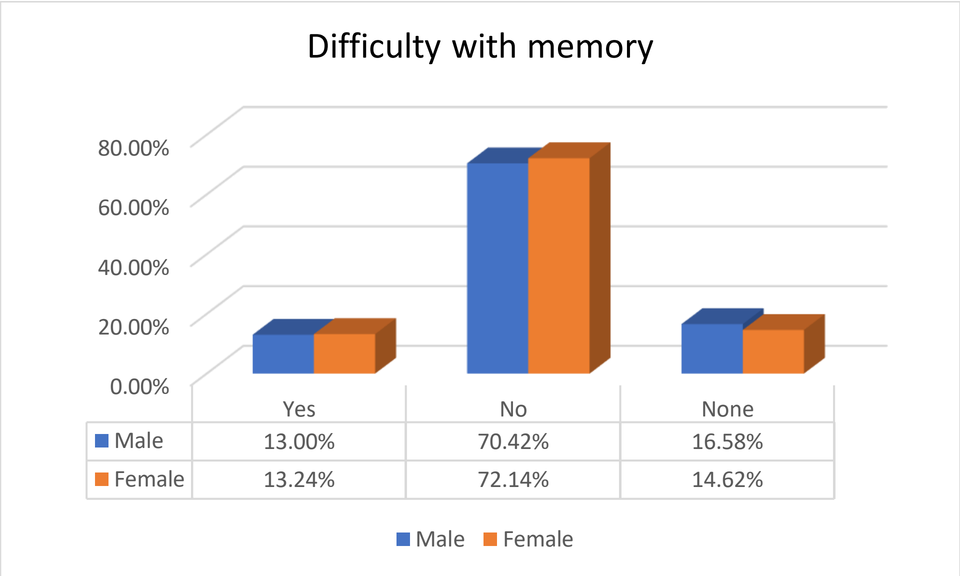
15a Frequency

Difficulty with memory	Yes	No	None	Total
Male	120	650	153	923
Female	154	839	170	1163

15b Percentage

Difficulty with memory	Yes	No	None	Total
Male	13.00%	70.42%	16.58%	100.00%
Female	13.24%	72.14%	14.62%	100.00%

15c Chart



F.3.5 Difficulty with stamina or breathing

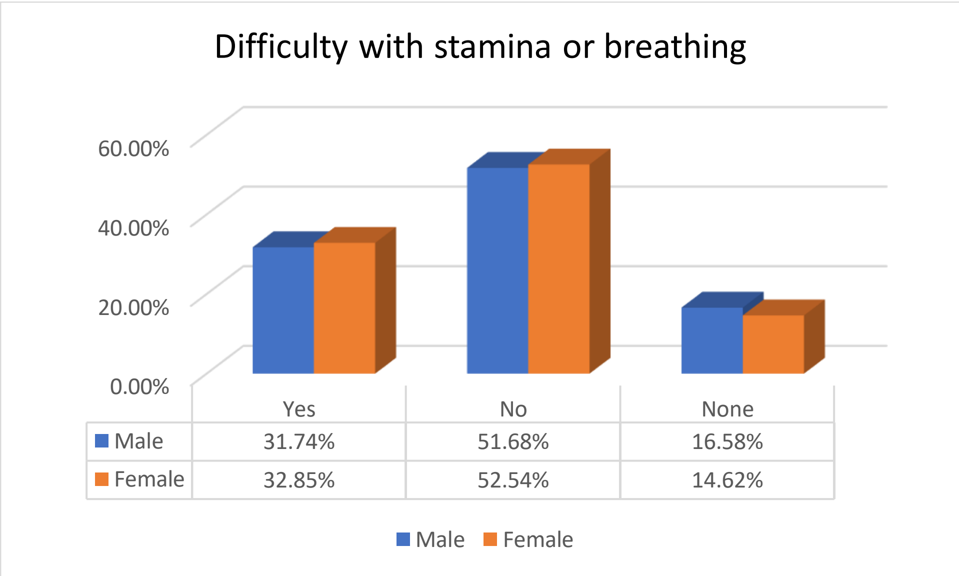
16a Frequency

Difficulty with stamina or breathing or	Yes	No	None	Total
Male	293	477	153	923
Female	382	611	170	1163

16b Percentage

Difficulty with stamina or breathing or	Yes	No	None	Total
Male	31.74%	51.68%	16.58%	100.00%
Female	32.85%	52.54%	14.62%	100.00%

16c Chart



F.4 Activity difficulties

This section provides information about the extent of hindrance exerted on the everyday activities of people that face difficulties with different capability types. The level of reduction of everyday activities of respondents, potentially due to difficulties with capabilities were referred to as "severity".

Using data from the same dataset, three levels of severity were identified:

- High severity, which is derived from the outcome "Yes, activities reduced a lot",
- Low severity, which is derived from the outcome "Yes, activities reduced a little", and
- No Severity, which is derived from the outcome "Not at all", which means that the respondents did not self-report any reduction in their everyday activities as a result of their difficulties.

These different severity levels are captured under the same broad categories of difficulties ("Yes", "No" and "None"), which were previously defined.

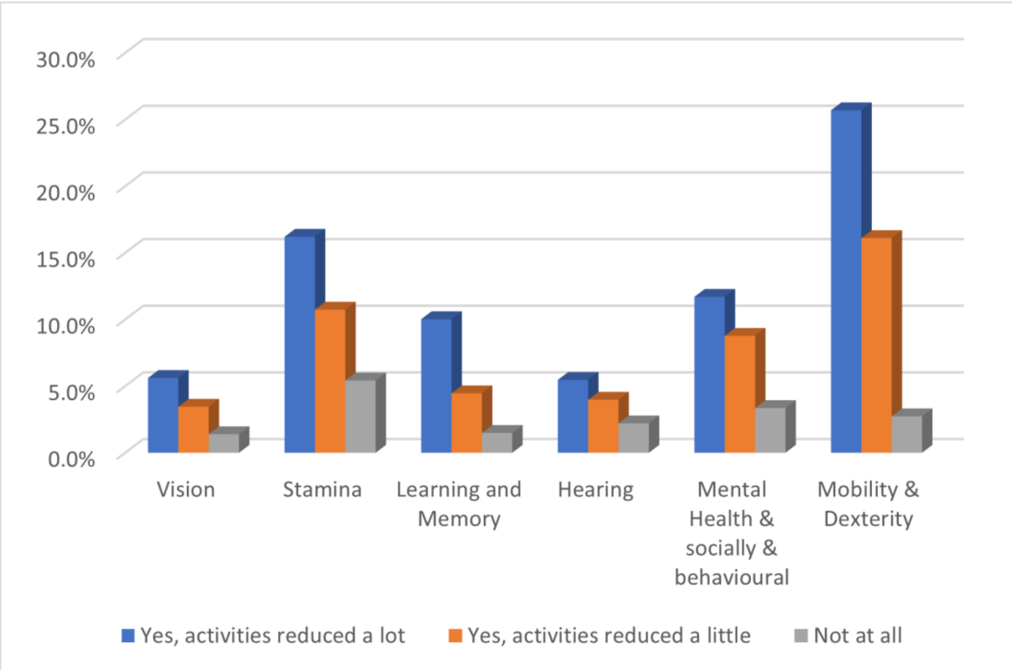
Table F1: Proportions of severity levels by capability type and self-reported difficulty

Severity		Vision	Stamina	Learning and Memory	Hearing	Mental Health, Socially & Behavioural	Mobility & Dexterity
Yes	**Yes, activities reduced a lot**	5.6%	16.2%	10.0%	5.5%	11.7%	25.7%
	Yes, activities reduced a little	3.5%	10.7%	4.5%	4.0%	8.8%	16.1%
	Not at all	1.4%	5.4%	1.5%	2.2%	3.4%	2.7%
No	**Yes, activities reduced a lot**	27.4%	16.8%	23.0%	27.6%	21.3%	7.3%
	Yes, activities reduced a little	30.2%	23.0%	29.2%	29.7%	24.9%	17.6%
	Not at all	16.4%	12.4%	16.3%	15.6%	14.4%	15.1%
None	**Yes, activities reduced a lot**	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%
	Yes, activities reduced a little	2.8%	2.8%	2.8%	2.8%	2.8%	2.8%
	Not at all	12.2%	12.2%	12.2%	12.2%	12.2%	12.2%
Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table F1 and Figure F3 show the different levels of severity for respondents having difficulties with each particular capability. For instance, 5.6% of the respondents mentioned that they have difficulties with vision and their activities have reduced a lot. Given that 10% of the sample has difficulties with vision, this statistic means that more than half of respondents with vision issues also face reductions in their activities to a significant extent. Interestingly, more than one out of four respondents in the sample (25.7%) have mobility and dexterity challenges and they also face significant reduction in their everyday activities. In addition, more than 16% of the respondents self-reported issues with stamina as well as a significant reduction in their activities.

Focusing on people with no difficulties with any of the listed capabilities (indicated by "None"), the vast majority of these do not face any activity reduction at all (15% is the total proportion of respondents with no difficulties in the sample, whereas 12.2% is the proportion of respondents with no difficulties who do no encounter activity reduction in the sample – in other words, more than 80% of people without difficulties with any of the listed capabilities do not face activity reduction in their life).

Figure F3: Proportions of severity levels for respondents with difficulties by capability type



G. Participant interview coding

G.1 Qualitative analysis

The interview recordings were downloaded and transcribed using a secure automated subscription service (Otter.ai). Following a corrective edit to mitigate errors of transcription the anonymous transcript was transferred to a thematic analysis software (QSR Nvivo) for coding of significant statements. Coding was based on modified Grounded Theory (Glaser & Strauss, Langdon et al 2010).

The resulting coding and frequency of occurrence of themes is summarised below. The codes were reviewed, recoded with a second coder, and collectively summarised with interpretation as a series of thematic findings. The findings from these interviews are covered in section 5 and in section 6 of this document.

G.2 Coding references

The qualitative data coding references in Table 5-3 are represented heirarchically based on frequency and content.

These were coded to groups by subject and topic:

- Street Properties
  - Moving through streets, crossings, road types, kerbs
- Strategies [for navigation]
  - Tactics in street, cues for crossing, use of assitance, on the street
- Capabilities
  - Sound, cane, orientation, training,
- General Remarks

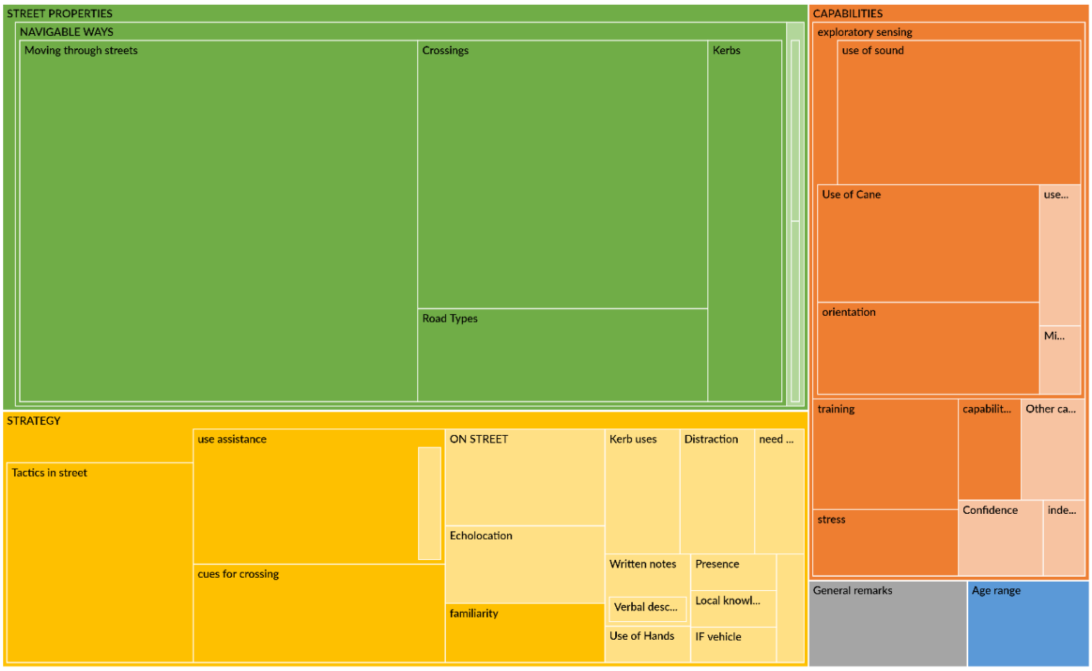
Methodology, such as meta-questions and researcher’s utterances, were coded to ‘Method’ where appropriate and this is excluded from the qualitative analysis thereafter. The complete code table is included in Appendx G.3.

The findings from these interviews is covered in section 6.

Table G1 - Top level code list

Name	Files	References
Strategy	2	82
Street Properties	2	58
Capabilities	2	15
Method	2	15
General remarks	2	4
Age range	2	3

Figure G1: Hierarchy area chart of frequency of coding references



G.3 Coding

Name	Files	References
STREET PROPERTIES	2	82
Hazards	2	10
Crossings	2	9
Cycleways	1	7
Tactile paving	2	5
Pedestrianised areas	2	5
Surfaces	2	5
side streets	2	4
Gradient	2	4
Kerb heights	1	4
Landmarks	1	4
road busy	1	3
Kerbs function	1	3
Parked Cars	1	3
Dropped kerbs	2	2
Memory	2	2
Green Man Crossing	1	2
noise	1	2
Lamp posts	1	1
Lights -crossings	1	1
Complex junctions	1	1
road works	1	1

Tramlines	1	1
DOGS	1	1
BIG CROWDS	1	1
STRATEGY	2	58
Tactics in street	2	12
use assistance	2	10
cues for crossing	2	8
ON STREET	1	5
Echolocation	1	4
familiarity	2	3
Kerb uses	1	3
Distraction	1	3
need for crossing point	1	2
IF vehicle	1	1
Use of Hands	1	1
Presence	1	1
Local knowledge	1	1
BAGS	1	1
Written notes	1	1
Method	2	15
questions	1	5
Consent	2	2
Sites	0	0
CAPABILITIES	2	15
training	2	4
stress	2	3
capability levels	2	2
Other capability needs	1	2
Confidence	1	2
exploratory sensing	1	1
independence	1	1
Aids to crossing	2	6
Maps apps	2	4
Tactile maps	1	1
General remarks	2	4
Age range	2	3
description	1	2
Bins	1	2
Journey	2	2
Elmbank street	1	1
Training	1	1
Byres Road	1	1
time of use	1	1

H. Documents

Edinburgh Napier University Transport Research Institute : Research Consent Form (Interview)

The inclusive Kerbs Project (iKerbs)

Consent form for the inclusive kerbs project run by Edinburgh Napier University Transport Research institute and the Engineering consultancy Mott Macdonald.

[Inclusive: to be read to participant in an online meeting]

Edinburgh Napier University requires that all persons who participate in research studies give their written/verbal consent to do so. Please read the following and indicate it if you agree with what it says.

1. I freely and voluntarily consent to be a participant in the research project on the topic of inclusive kerbs run by Edinburgh Napier University Transport Research institute and the Engineering consultancy Mott Macdonald. "New inclusive kerbs for Scotland" to be conducted by Professor Pat Langdon, who is a staff member at Edinburgh Napier University.
2. In brief, this initial project will address the issue of kerb heights and the problems they present to people from a population with a wide range of abilities.

   The Transport Research Institute will be working with global Engineering consultancy Mott MacDonald to look at the best designs of kerbs for the future in Edinburgh. Sponsored by the Scottish Road Research Board (SRRB), they will select good examples of basic kerbs that meet requirements of Transport Scotland and examine them from the point of view of people crossing. Specifically, You have been asked to participate in an interview, which should take around 60 minutes. The interview will be recorded and deleted after transcription. You have the right to delete any or all of the recording if you wish up until deletion.
3. I have been told that my responses will be anonymised. This means that my name will not be recorded on any documentation and that only the researchers will have access to records. You will not be linked with the research materials, and will not be identified or identifiable in any report subsequently produced by the researcher.
4. I also understand that if at any time during the interview I do not wish to continue, I am free to withdraw. That is, my participation in this study is completely voluntary, and I may withdraw from it without negative consequences. Any data already collected, however, will remain as it may compromise the study findings to remove it and/or may no longer be identifiable within the dataset. I understand that the anonymised data may be re-used after it is lodged in public storage.
5. In addition, should I not wish to answer any particular question or questions, I am free to decline.
6. I have been given the opportunity to ask questions regarding the interview group and my questions have been answered to my satisfaction.

Edinburgh Napier University Transport Research Institute : Research Consent Form (Interview)

7. I have read, or heard, and understand the above and consent to participate in this study. My signature is not a waiver of any legal rights. Furthermore, I understand that I will be able to have a copy of the informed consent form for my records.

Participant's verbal agreement or Signature Date

I have explained and defined in detail the research procedure in which the respondent has consented to participate. Furthermore, I will retain one copy of the informed consent form for my records.

Researcher's Signature Pat Langdon Date 8/3/22

p.langdon@napier.ac.uk V10

Edinburgh Napier University Transport Research Institute (ENU – TRI)

The inclusive Kerbs Project (iKerbs)

Call for Participation for the inclusive kerbs project run by Edinburgh Napier University Transport Research institute and the Engineering consultancy Mott Macdonald.

"New inclusive kerbs for Scotland"

In brief, this initial project will address the issue of kerb heights and the problems they present to people from a population with a wide range of abilities.

The Transport Research Institute will be working with global Engineering consultancy Mott MacDonald to look at the best designs of kerbs for the future in Edinburgh. Sponsored by the Scottish Road Research Board (SRRB), they will select good examples of basic kerbs that meet requirments of Transport Scotland and examine them from the point of view of people crossing.

Initially the team will look at the kerbs that separate the pavement from the road; the kerbs between the pavement and cycleway, and the kerbs separating the cycleways from the roadway. The choice of sites for the study will also be made on other properties of a crossing scenario, such as gradient, height differences, colour of kerbs and surfaces; noise characteristics of the crossing point and how busy the crossing point is in terms of traffic density and character.

The overall aim is to look at improving street layouts for inclusion; hence, the project will ask people who represent inclusive populations their opinions and experiences of kerbs during crossing. To be most useful, the team will engage with people whose capabilities vary in the areas of vision, hearing, physical movement, and thinking ability.

To that end, we are asking organisations such as RNIB, Guide Dogs Scotland, RNID and others such as Motability and National Autistic Society (NAS), to put out a call to affiliates and associates for people interested in taking part in the consultation phase of the project over December 2021 to March 2022.

The outcomes form this consultation stage in the project will be used to plan follow up work in 2022 using real physical kerb simulations in a controlled lab

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environment. There will be further opportunities to participate in these studies if you are interested in doings so.

HOW WE CONTACT YOU

Firstly, we would contact you on email, electronic chat or telephone, to ensure you were happy to participate, and then I would arrange a follow up Phone or computer-based call. For the computer call we use software such as Zoom, Google meetings, Microsoft teams, and Webex, some of which will also be available on mobile devices such as tablets or even smartphones such as iPhones, or android devices.

We would schedule an interview about a number of specific kerb sites in Edinburgh with visual aids such as pictures and videos if they were usable. We are interested in physical difficulties that may present themselves in engagement with kerbs and surfaces at the specific crossing point. We are also interested in mental and physical workload, and understanding, perceived stress, apprehension, ease of use, and comfort.

The interview would be as long as you want and follow-ups can be scheduled. We can also arrange a face-to-face interview under Covid separation conditions at one of our campus sites at Merchiston or Craiglockheart. We will compensate you for travel expenses.

Please contact Prof Pat Langdon at Napier e-mail: p.langdon@napier.ac.uk for more information or the TRI project support officer Yvonne Lawrie(y.lawrie@napier.ac.uk) for more information.

The 'phone number for this is: 0131 455 2951 Or Tel: 0131 455 2617

Additional Details

The leader of the project from the Edinburgh Napier University side is Prof Pat Langdon (p.langdon@napier.ac.uk), who has a background in inclusive design and human interface ergonomics. The Mott Macc side is led by transport Engineer, John McLennon. (john.maclennan@mottmac.com).

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The ENU Transport Research Institute is a longstanding University transport research group that has been in existence since 1996 (https://blogs.napier.ac.uk/tri/). It is Scotland's largest and longest established transport research group and is an advisory body on Scottish transportation policy. It continues to maintain the reputation of the TRI brand and develop a high level of public, governance and planning research influence both national and international.

The Mott MacDonald Group is a consultancy headquartered in the United Kingdom. It employs 16,000 staff in 150 countries. Mott MacDonald is one of the largest employee-owned companies in the world. It was established in 1989 by the merger of Mott, Hay and Anderson with Sir M MacDonald & Partners. Scotland is currently experiencing an exciting renaissance in infrastructure development, guided by the COP26 global climate change conference in Glasgow this year and a Scottish Government programme focused on Scottish economic growth. Sustainable infrastructure development continues at pace, with opportunities on the Trunk Road network and significant City centre initiatives. Its e-mail in Scotland is edinburgh@mottmac.com p.langdon@napier.ac.uk V2 DRAFT Interview online

Edinburgh Napier University Transport Research Institute (ENU – TRI) and Mott MacDonald

INTERVIEW SCHEDULE for the inclusive Kerbs Project

NOTE: This version is for Pilot stage consultation

In brief, this initial project will address the issue of kerb heights and the problems they present to people from a population with a wide range of abilities. The Transport Research Institute is working with global Engineering consultancy Mott MacDonald to look at the best designs of kerbs for the future in Edinburgh. We are interested in your experiences of some kerbs that meet the requirments of Transport Scotland and examine them from the point of view of people crossing.

Initially the team will look at the kerbs that separate the pavement from the road; the kerbs between the pavement and cycleway, and the kerbs separating the cycleways from the roadway. The overall aim is to look at improving street layouts for inclusion; hence, the project will ask people who represent inclusive populations their opinions and experiences of kerbs during crossing. To be most useful, the team will consider people whose capabilities vary in the areas of vision, hearing, physical movement, and thinking ability.

The outcomes form this consultation stage in the project will be used to plan follow up work in 2022 using real physical kerb simulations in a controlled lab environment. There will be further opportunities to participate in these studies if you are interested in doings so.

HOW WE PROCEED ONLINE

Following an initial call we have arranged a follow up Phone or computer-based call. For the computer call we are using software such as Zoom, Google meetings, Microsoft teams, and Webex, some of which will also be available on mobile devices such as tablets or even smartphones such as iPhones, or android devices.

We have compiled a list of a number of specific kerb sites in Edinburgh with visual aids such as pictures and videos if they are usable. The choice of sites for the study will also be made on other properties of a crossing scenario, such as gradient, height differences, colour of kerbs and surfaces; noise characteristics of the crossing point and how busy the crossing point is in terms of traffic density and character. This document will be sent to you in advance and descriptions read out, captioned, or can be signed (BSL) during the interview.

1

[FOLLOWING CONSENT- see consent form]

Part 1 GENERAL QUESTIONS

1. Which age group are you in?
    a. 1-29/30-44/45-59/60-74/75-85/85+
    b. What best describes your gender?
    c. How would you describe your capability in the following areas:[1=Not at all affected 2,3,4,5,6, 7=Extremely affected.] (for coding – will not be asked).
        i. Vision
        ii. Hearing
        iii. Physical Movement
        iv. Thinking Issues
        v. Other Capability Issues (e.g. Heart Disease, Asthma, ...)
        vi. Requiring Assistance
2. Would you say you experience any difficulty with crossing roads in General? WOULD YOU LIKE TO GIVE ANY GENERAL REMARKS ABOUT YOUR EXPERIENCES WITH CROSSING KERBS IN SCOTLAND?
3. Do you live in Edinburgh? How long?
4. Are you familiar with crossing roads?
5. Do you require assistance to cross roads?
6. Do you need to cross with a wheelchair/Pram/Bags or Trollys?

The sites chosen for the study have been sent to you in advance they are as follows

[List sites in table]

2

Column1	Location	Purpose in Study
Location 1	York Place	Cycling
Location 2	Elder Street	Pedestrianised
Location 3	High Street	High kerbs
Location 4	Constitution Street	New build / drains
Location 5	Buchannan Street	Quiet Road
Location 6	Dundas Street	Complex road
Location 7	George Street	Pedestrianised

If you are familiar with any of these we will start with that.

Site descriptions (brief summary)

1. York Place – Outside the Playhouse

Approaching downhill from the Omni Centre, a widened plaza with steps narrows to a smaller plaza with different patterned slabs. The slabs are new, smooth and dark grey. A controlled pedestrian crossing on your left crosses the cycleway and the road. The tackle paving is close into the crossing point with no tail.

Turing left to facing the road behind you is the Playhouse Theatre. Infront is a line of slabs, flush with surrounding marking a change in angle of the footway as it slopes up to the cycleway. At the top of the slight slope there is a new low angled kerb down the cycleway. The cycleway is black asphalt and dark red chips, about 1.5m wide, with another low angled kerb up to a narrow cobbled strip segregating it from the carriageway.

You can hear a street with buses, lorries and cars continuously stopping and starting at, and driving through, the traffic lights and roundabouts nearby. There are pedestrians passing in sporadic frequency but not crowding. The occasional cyclist will approach and pass on the cycleway.

The area is wide open and exposed.

2. Elder Street

Elder Street is a shared surface area between Multrees Walk and the St James Centre. The bottom of the street gives access to the St Andrews Square bus terminal. We will be up the street away from this area. Approaching from the pedestrianised shopping area of Multrees walk ahead of you is the St James Centre. The footway on Multrees walk is smooth light grey granite slab with ornamental concrete sets. Turning right you face up the slope of Elder Street. The light grey slabs continue on the right side of the street. The road carriageway is jointed concrete brick, and the footway is a mix of smooth ochre yellow brown slabs.

The kerb on the left side is a bright grey granite with a low step with a matching granite shallow u-shaped drainage kerb adjacent.

On the right-hand side there is a parking and loading bay extending up the hill.

Away from the entrance into the St James Centre the street has few pedestrians and few vehicle movements. The noise and movement of the bus terminal is distant.

The area bright and new. It is between high modern buildings but is not narrow or enclosed.

3. High Street (The Royal Mile)

Outside the Hector Russell, opposite the Radisson Blu Hotel downhill from the junction with North Bridge. Approaching up the hill towards the castle. At 'The Mitre' bar the smooth dark grey granite slab pavement widens slightly. On the right is the bar, and ally close, and the Hector Russell kilt shop.

On your left is there are sign columns, black bins, a red letterbox, and a short dark cabinet.

The footway here often has other street furniture, such as tables, chairs, partitions, and advertising.

The smooth dark granite kerb is wide and high, with a matching smooth dark granite drainage channel at its base. Along the outside of the drainage channel double yellow lines are painted. The road is a mix of raised dark and light cobbles, with rough, uneven depressions and asphalt repairs.
A taxi rank with waiting taxis is on the right side of the carriageway, outlined in yellow and with a darker set of smooth cobbles. The kerb and drainage on the right side of the road is identical to the left. The footway is the same dark grey granite, but wider and without posts or obstructions.
The noise and movement on North Bridge is continuous, with vehicles turning into the street at the signalised junction. There are often crowds gathering and crossing nearby. On the High Street in front of you there is a frequent passage of cars, buses, and delivery vehicles on the cobbled street.
The area is between high old buildings with ornate fronts. Road and foodway widths vary between narrow and enclosed and open.

4. Constitution Street

The section of Constitution Street between Baltic Street and Ocean Drive. Newly installed for the trams. Approaching, from the Albert Dock Cranes walking back towards the city. The section of Constitution Street between Baltic Street and Ocean Drive. Newly installed for the trams.
Approaching, from the Albert Dock Cranes walking back towards the city.
Along your left hand runs along a stone wall, with one double width gateway, after which the wall continues until it reaches a sandstone building with a roller gate and large windows. Closer to the junction with Baltic Street the building becomes more ornate with frequent large windows. The lighting columns are brown and set to the back of the footway.
On your right-side cars are parked along the length of the kerb, except at the locations with gates.
The footway is about two people wide, new smooth grey granite stone slabs with a light grey concrete kerb. The kerb is a drainage kerb with approximately tennis ball size holes in the vertical face to allow water to enter.
The road carriageway is approximately four lanes wide (including the parking) and is back asphalt until it reaches the tram tracks where it is a light grey concrete with dark inset rails.
The road has the occasional delivery truck and car. The adjacent Baltic Street junction is busy with heavy vehicles and cars.
The area is a mix of new and old buildings, residential, commercial, and industrial uses.

5. Buchannan Street

Approaching from the city, heading down the hill from Iona Street towards Leith.
Along your left side the street consists entirely of tenement buildings. The footway is rough old black asphalt with litter and damp areas periodically. It is approximately two people wide. The kerb is old dark grey stone. Along your right side is double parked cars and large communal bins.
The road is four lanes wide, but with double parked cars on both sides of the street it leaves the driveable width of the road only one car width wide. Traffic is singular, slow, and infrequent.
The noise of Leith Walk is present in the background.
The area is narrow and enclosed, boxed between tenements on all sides.

6. Dundas Street

Approaching uphill, towards Queen Street and the city centre. That section of Dundas Street between Great King Street and Northumberland Street, at the bus stop opposite the Tesco Express.
As you progress up the hill on your left-hand side there are shop fronts and cafes set back from the footway, with black metal railings along the footway. The lighting columns and bins are on the outside edge of the footway, next to the road.
The footway is approximately four or five people in width and is bright smooth grey concrete slabs.
The kerb is dull grey and low to the road. The road is a mix of asphalt patches.
The road four lanes wide and is busy with buses, cars, and lorries. They are manoeuvring and parking alongside the pavement on both sides.

7. George Street

Outside the Royal Society of Edinburgh. Under partial road closure at time of survey. The footway is of old broken red and grey slabs approximately four to five people wide with a dark grey kerb. On the footway to your right on the roadside is a large yellow and black bin. Opposite that is red partitioned outdoor seating against the restaurant. Cars are parked along the road edge.
The carriageway is two and a half lanes wide, with a cycleway in the centre. In the middle of the street there is a cobbled parking which is full. On the other side is another two and a half lanes wide with a cycleway and parking along the kerbside.
Currently the carriageway in front of you is closed with red and while plastic barriers forming a small cul-de-sac. Traffic is only moving on the far two lanes in one direction (from left to right). The traffic is a mix of cars, buses, and delivery vans.
There are groups of people and individuals passing and moving along the footway and over the road.

End of SHORT Site Descriptions

[FOR EACH SITE OR CHOSEN SITE]

[Read Site Descriptions]

- How familiar are you with this crossing point? That you use …(Very – Not at all)?
- How often do you visit the locale of this site?
  - Once a day/week/month/occasionally/rarely
  - At what time, roughly?
- Why do you visit this locality?
- Why is it necessary to cross?
- Would you use an established crossing if it exists?
- What are your main considerations if choosing a crossing place?
- Do you have any specific issues with your abilities at this crossing point? [as applies]
  - Are there Visual difficulties with this crossing point?
  - Are there Hearing difficulties with this crossing point?
  - Are there Understanding/memory difficulties with this crossing point?

- Any physical difficulties that may present themselves in engagement with kerbs?
- Or surfaces at the specific crossing point?
- What is the best route and approach to the crossing point- Why?
- What is the overall effort to cross?
- How stressful is crossing at this point?
- Would you be apprehensive at this crossing point?
- Any other issues at this specific site (dexterity/parking/pedestrians/dogs/cyclists/proximity to hazards)

- Are there any crossing places in your experience that you feel comfortable with, that are easy to cross?
- Would you avoid certain crossings at some times of the Year?
- Have you any other comments or statements you would like to make regarding kerbs at crossings?

Would you be interested or prepared to make a site visit to some of these crossing points under safe supervision? How can we contact you?

[End of Interview]

End of SHORT Site Descriptions

Please contact Prof Pat Langdon at Napier e-mail: p.langdon@napier.ac.uk for more information or the TRI project support officer Yvonne Lawrie(y.lawrie@napier.ac.uk) for more information.

The 'phone number for this is: 0131 455 2951 Or Tel: 0131 455 2617

Additional Details

The leader of the project from the Edinburgh Napier University side is Prof Pat Langdon (p.langdon@napier.ac.uk), who has a background in inclusive design and

6

human interface ergonomics. The Mott Macc side is led by transport Engineer, John McLennon. (john.maclennan@mottmac.com).

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I. Selected full quotes

I.1.1 Cycle tracks

A particular crossing intersection in Glasgow is Elm Bank / Sauchiehall Street (Google Maps, 2022) was discussed in this unedited interview excerpt:

Participant: “That you have to worry if you want to cross the, the whole width of the cycle way and, and the road and the carriageway. There are no kerbs.”

Researcher: “You get really”

Participant: “I mean there are kerbs where you don't want to cross. But they've raised the way. What do you call it? A raised table on the road?”

Researcher: “Yeah.”

Participant: “Which of course eliminates the kerbs? Because haven't raised the pavement.”

Researcher: “So it's sort of a ramp right, terrible?”

Participant: “Yeah. Well, yes, a ramp for the traffic, but no kerbs, it ends up making the road the same height as the pavement. Therefore, you don't know when you've crossed cycle track, and you don't know when you're on the vehicle bit. And it's absolutely awful.”

I.1.2 Road types

Pedestrianised areas were perceived as particularly problematic, as discussed in this unedited interview excerpt:

> Researcher: “Do you find pedestrianised area challenging?”
>
> Participant: “Yeah. Well, yes, but that's because they tend to be littered with street furniture and stuff.”
>
> Researcher: “Oh, I see. Yeah”
>
> Participant: “that's one problem. And the other problem is right? So, if it's a pedestrian street that was the traffic street before and has been pedestrianised. Normally, they would leave the pavements in place. But, but you wouldn't be expected to walk on them, because they have all sorts of clutter on them. So, the obvious thing to do is to walk down the middle of the street? Oh, which is absolutely fine. I'm completely fine with that. Except when you come to a crossing a road with traffic on it. So, you don't get the signal that you would do if you're walking on the pavement. So, there's a bit of a tension between whether to try and work on the pavement in spite of all the planters and bike racks and shop

> displays and stuff, or to walk down the middle and hope that you'll hear the traffic on the crossing road before you step out into it. So, any pedestrian areas are not nearly as useful or congenial for, for for me as, as you might expect, or wish."

I.1.3 Kerbs

Severely visually impaired participants did not perceive kerb height as important, as long as the kerb was high enough to be detected by a cane. As discussed in this unedited excerpt from an interview:

> Participant: "I don't think that the height of the curve, unless it's ridiculous one, like the one I've talked about in the non-kerb in the Sauchiehall street/Elmbank junction. I don't think the kerb needs to be that high for my purposes."
>
> Researcher: "Right."
>
> Participant: "As long as it's consistent and distinctive, see what I mean."
>
> Researcher: "But it can be too, obviously, it can be too high."
>
> Participant: "Yeah. Yeah, I suppose it's a bit inconvenient if it's if it's a high. And obviously, it's terrible, obviously, terrible for wheelchairs. So, I mean, at the point where I would mostly want to cross, I would expect it to be dropped anyway."

I.1.4 Exploratory Sensing

Unedited excerpt from interview:

> Participant: "it's a mixture of the noise of the cane. I mean, I don't sort of tap hard with it, but it does make a noise and your footfall as well. I think those are the main things. And you're getting, you're getting a signal from solid objects, especially solid objects beside you, rather. It's easy to detect on objects next to you rather than in front of you, interestingly. So, but echolocation is very useful for navigating a straight line along a pavement in a built-up area where you generally an assortment on your left or right or whatever it is."

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