

Measuring Accessibility as Experienced by Different Socially Disadvantaged Groups

Funded by the EPSRC FIT Programme

Working Paper 6

Developing Accessibility Planning Tools

Updated

June 2005

CONTENTS

EXECUTIVE SUMMARY	4
1. INTRODUCTION.....	6
2. STRATEGIC LEVEL ACCESSIBILITY TOOLS	7
2.1 UK ACCESSIBILITY PLANNING TOOLS	7
2.2 PTAM	7
2.3 CAPITAL	8
3. STRATEGIC LEVEL ACCESSIBILITY TOOL ENHANCEMENTS.....	11
3.1 PTAM: AGREED TOOL ENHANCEMENTS	11
3.1.1 Making the Enhancements.....	11
3.1.2 PTAM Accessibility Plots	12
3.2 CAPITAL TOOL ENHANCEMENTS	13
3.2.1 Making The Enhancements.....	13
3.2.2 CAPITAL Accessibility Plots	14
4. THE 'WEIGHTED ACCESS FOR LOCAL CATCHMENTS' TOOL	17
4.1 LOCAL LEVEL ACCESSIBILITY: THE 'WALC' TOOL.....	17
4.1.1 Current treatment of walk access in PTAM and CAPITAL accessibility tools	17
4.1.2 Summary of basic approach adopted in developing WALC	17
4.2 REPRESENTATION OF THE PEDESTRIAN NETWORK.....	17
4.2.1 Street Audits.....	18
4.2.2 Pedestrian network data availability	19
4.2.3 Adding Duplicate Links and Nodes	19
4.3 ESTIMATING WEIGHTING FACTORS	20
4.3.1 Survey Methodology.....	20
4.3.2 Developing Walk Time Penalties and Ratios.....	20
4.4 EMPIRICAL ESTIMATES: KEIGHLEY.....	22
4.4.1 Gradients (Keighley only)	23
4.4.2 Bus stop conditions	23
4.4.3 Crossing the road	23
4.4.4 Lighting levels.....	23
4.5 EMPIRICAL ESTIMATES: TOWER HAMLETS	23
4.5.1 Certainty of boarding first bus (Tower Hamlets only)	24
4.5.2 Bus stop conditions	24
4.5.3 Crossing the road	24
4.5.4 Lighting levels.....	25
4.6 APPLYING THE WEIGHTING FACTORS	25
4.6.1 Crossing	25
4.6.2 Gradient.....	25
4.6.3 Lighting.....	25
4.6.4 Bus Stop Conditions	26
5. ACCESSIBILITY MAPS	27
5.1 'WALC' OUTPUT MAPS	27
5.2 VALIDATION OF OUTPUTS.....	28

6.	RECOMMENDED FURTHER WORK.....	30
6.1	STRATEGIC ACCESSIBILITY TOOLS.....	30
6.1.1	Addition of boarding capacity constraint.....	30
6.1.2	Adoption of weighted travel times.....	30
6.1.3	Relating access to demand.....	31
6.2	'WALC' TOOL.....	31
6.2.1	Measuring walk speeds.....	31
APPENDIX 1: OPTIONS FOR CREATING DETAILED WALK ACCESS NETWORKS		33
APPENDIX 2: STATISTICAL DIFFERENCES IN WEIGHTS BY GROUP		40

EXECUTIVE SUMMARY

The University of Westminster's Transport Studies Group received funding from the UK Engineering and Physical Sciences Research Council (EPSRC) to develop more refined and sensitive measures of accessibility that take into account the concerns of various socially disadvantaged groups. The partners for this project included: Transport for London (TfL), the London Borough of Tower Hamlets (LBTH), West Yorkshire PTE (METRO) and Bradford Metropolitan District Council (BMDC).

The research focused on seven socially disadvantaged groups: young people (16-24), older people (60+), Black and Minority Ethnic (BME) people, disabled people (physically disabled people and people with mental health illness), people travelling with young children (aged 11 or under), unemployed people and shift workers. It was divided into seven phases, starting with literature reviews of user needs¹ and current accessibility planning concepts and tools², through data collection³ (both of public attitudes / behaviour and local bus stop / street conditions) to parameter specification and application, and validation of the two enhanced tools (CAPITAL in London and PTAM in West Yorkshire) among user groups⁴.

At the strategic level, accessibility models and tools can be used to explore the effects of poor public transport provision in a quantifiable and systematic way. The findings of a desk-based literature review have shown that existing tools are not configured in ways that are sensitive to the varying needs and perceptions of different social groups (e.g. their need and physical / psychological ability to access different goods and services at different times of the day and on different days of the week; the resources at their disposal, in-vehicle travel times, and the local availability of suitable transport and land use facilities).

At a local level, local authorities require a tool that helps them to understand and codify the needs of different social groups (e.g. types of activity, by time of day), and to establish how easily people can reach suitable locations where they can carry out these activities, taking into account local transport provision in ways that reflect user perceptions. In other words, to develop accessibility tools able to capture the ways in which different social groups perceive and use their local environment. This requires a detailed mapping of objective transport provision (public transport nodes, bus services etc), incorporation of wider concerns (e.g. local street conditions, gradients, crossing points and lighting levels) and an awareness of the relative importance that different groups place on attributes of a particular type of journey (e.g. walking times and distances).

This report summarises the enhancements that were made to the two existing strategic accessibility measuring tools (CAPITAL used by TfL and PTAM used by METRO) and introduces a new, free-standing tool that was developed by TSG researchers to reflect perceived walk access conditions, called 'WALC' (Weighted Access for Local Catchments).

The report is divided into six sections: the first section introduces the project, in particular its aims and objectives and provides a brief summary of the fieldwork findings. Section two introduces the two strategic level accessibility tools that were adapted as part of this project (i.e. PTAM used by METRO and CAPITAL used by TfL) and highlights the limitations of both. This is followed, in section three, by an outline of the main enhancements that were made to the two accessibility tools during the course of this project.

¹ Working Paper 1: User Needs Literature Review (WP1)

² Working Paper 3: Accessibility Analysis Literature Review (WP3)

³ Working Paper 2: Social Groups User Needs: Survey Findings (WP2); Working Paper 4: Bus User Walk Access Barriers (Keighley) (WP4); and Working Paper 5: Bus, DLR / Underground Walk Access Barriers (Tower Hamlets) (WP5).

⁴ Working Paper 7: Feedback on New / Enhanced Tools from Social Groups (WP7).

The WALC tool is explained in section four, in particular the steps that were taken to develop the tool, the data requirements and weighting factors. Section five describes the process of creating walk access catchments and provides some illustrative examples. Finally, section six identifies several areas for further investigation, both relating to strategic accessibility tools as well as the WALC tool.

1. INTRODUCTION

At a national policy level, the importance of accessibility for promoting social inclusion was clearly recognised in the UK Social Exclusion Unit (SEU) 2003 report⁵ on 'Making the Connections: Transport and Social Exclusion'. The report identified transport as a significant barrier to social inclusion and this has led to the emergence of a new framework for Accessibility Planning in England, in which transport professionals are required to base aspects of transport planning on access requirements rather than on traffic or mobility needs; comparison with other G7 Countries indicate that the English work is world leading in this respect⁶. However, relatively little is known about the accessibility needs of different socially disadvantaged groups and how these needs are included, if at all, within current accessibility planning tools.

The University of Westminster's Transport Studies Group have undertaken a 2.5 year project to develop more refined and sensitive measures of accessibility that take into account the concerns of various socially disadvantaged groups. As part of this study the research team have carried out a desk-based review, of both published and grey literatures and an analysis of existing data sources (see WP1), plus a series of focus groups and depth interviews (see WP2) to explore the following issues amongst the different socially disadvantaged groups: travel patterns, suppressed travel demand and preferred activity patterns, key journey and destination attributes, the relative importance of these attributes and threshold values for maximum walking distances and waiting times.

The survey findings have highlighted many barriers, common to all groups, including: limited travel choices (both spatially and temporally); excessive walk access distances to public transport services and various problems encountered on route; the time required to reach destinations (compared to going by car); poor service reliability (services cancelled and delayed); limited availability of public transport information in a suitable format; and the cost of using public transport. However, the impacts and intensity of these barriers did vary between population groups and times of day.

This Working Paper reports on the project's aim to enhance the strategic accessibility tools used by METRO (PTAM) and Transport for London (CAPITAL), as well as the unforeseen development of a new walk access tool called 'WALC' (Weighted Access for Local Catchments). This tool has been designed specifically to better represent public transport passenger perceptions of the pedestrian access network, by showing how standard walk catchment areas change shape and shrink once the impedance effects of different types of barriers on various population groups are taken into account.

⁵ Social Exclusion Unit (2003) *Making The Connections: Final Report on Transport and Social Exclusion*, HMSO, London.

⁶ Lucas, K. (2004). *Transport and social exclusion: a G7 comparison*. FIA Foundation, London.

2. STRATEGIC LEVEL ACCESSIBILITY TOOLS

2.1 UK ACCESSIBILITY PLANNING TOOLS

There is a well established, international literature dealing with accessibility, going back over 40 years (e.g. Hansen, 1959), drawing largely from geographical studies (see WP3). In general, conventional accessibility measures incorporate three components (Geurs et al, 2001): (i) a given geographical 'origin' location (usually a small zone), (ii) a set of relevant destinations (employment areas, shopping centres, as appropriate, which may be weighted according to size / quality) and (iii) a measure of the physical separation between (i) and (ii). The latter may be defined in terms of distance, time or generalised cost. Accessibility can then be presented in a number of ways: as an index, or as some form of potential measure (e.g. N jobs within 15 minutes).

With the advent of increasing computer power, various electronic data sets and GIS systems, it has become practical to operationalise such measures and apply them to a whole urban area or region. One of the first accessibility models to be applied as a practical planning aid in the UK was the 'PTALS' model, developed by the London Borough of Hammersmith and Fulham⁷. This focuses either on the origin or the destination end of the trip and uses a simple formula to measure the intensity of public transport provision at various stops within easy walking distance of each site or area. These measures are aggregated and grouped into six bands of Accessibility Level, and can then be plotted as an isochronal map. Unlike the other models referred to below, it does not take account of travel times **between** trip origins and destinations.

Most of the new breed of UK commercially available accessibility planning tools (e.g. ACCMAP and TRANSAM) have been based on simplified journey planning approaches, using Ordnance Survey land use information and public transport timetable data to define networks and services. The tools provide journey access and travel time mapping packages, identifying the best routes from origins to destinations (taking account of walk times to cars or public transport services, wait times and in-vehicle times), and show outputs in the form of isochrones, shaded maps, bar charts etc.

The recently developed Accession tool, by MVA on behalf of the DfT, has the ability to calculate many more origin and destination combinations and to output a wider range of indicator types. The tool aims to address some of the main constraints of previous products including:

- Reducing the time consuming process of calculating and presenting multiple trip purposes to multiple destinations;
- Many include subjective views of need, making their use in accessibility planning problematical, particularly where objective measures are needed; e.g. SONATA (Steer Davies Gleave).
- Representation of demand responsive services is problematical; and
- Data importing, validation and network editing has been very time consuming.

The two accessibility planning tools adapted as part of this project (i.e. PTAM and CAPITAL) are representative of two different types of commonly applied accessibility planning tools, and they were not sensitive to the varying accessibility concerns of different groups of people. Although, the tools differ in coverage and complexity, both can provide measures of accessibility to single points or to related sets of points (e.g. hospitals).

2.2 PTAM

METRO's "Public Transport Accessibility Mapper" package is an integrated GIS-based accessibility mapping tool that draws on the following primary data sources:

- (i) METRO public transport databases containing timetables, stops and routes;

⁷ London Transport, (1999) *Calculator for Public Transport Accessibility in London (CAPITAL)*, Technical Note, July.

- (ii) Census statistics, covering a wide range of population characteristics;
- (iii) NOMIS data, covering employment location characteristics;
- (iv) OS mapping showing various physical features, road networks and administrative boundaries; and
- (v) Facilities databases, covering details of the provision of education, retail, health and leisure services.

The tool is designed to provide an estimate of the accessibility of a location, or set of locations, and can output both origin and destination-based indicators. It has been widely used as a policy tool, for example in developing Urban Bus Challenge schemes, and is used in negotiations with developers over Section 106 planning agreements at particular sites. The package is able to define location(s) either via on-screen OS mapping, or through user selection from a facilities database and presents the outputs as three main types: (i) available opportunities; (ii) location-specific opportunities and (iii) multi-location opportunities. Walk access to bus stops is measured as a simple, straight-line distance, and so represented as a circle of 400m radius around each stop.

The five main stages of an application are as follows:

1. All bus stops within a defined straight line walking distance of a location, or set of locations, are identified.
2. Routes serving each of these stops are identified and, from information on service frequencies in a specified time period, bus waiting times are calculated.
3. Bus journey times from the starting point(s) to bus stops along the identified routes are calculated.
4. Walking catchment areas from the alighting stops along the identified route(s) are estimated.
5. Overall journey times and catchment areas are defined and the facilities / populations within them are listed/mapped.

The results of the analysis can be viewed either as isochrones on an OS background, showing bus stops and relevant facilities, or as tables containing census statistics, employment statistics, and lists of facilities and their attributes.

One of the main strengths of the PTAM tool is that it can calculate accessibility at different times of the day, as well as days of the week because it uses a bus timetable database. However, the limitations of the then current version of the tool include an inability to measure accessibility using all modes of public transport (restricted to bus network accessibility); and an inability to calculate journey times using more than one bus (absence of an interchange function).

2.3 CAPITAL

CAPITAL stands for "CalculAtor for Public Transport Accessibility in London". It is Transport for London's tool for measuring accessibility to a specific destination/set of destinations, or from a specific origin/set of origins. It takes into account all the main aspects of journey time (i.e. walk access time, waiting time, in-vehicle time and interchange time).

The walk access times to/from locations are calculated using the smallest geographical unit in the Census hierarchy, that of the Enumeration District (ED). There are around 15,000 EDs in Greater London, each containing approximately 200-300 households, or 400-500 people. Each ED is given a defined centroid to/from which access times are calculated; this is the (weighted) centre of population within that zone.

The CAPITAL tool combines information from Transport for London's Planning and Development Geographical Information System (PDGIS) and its public transport assignment model (RAILPLAN). PDGIS is used to calculate the walk access times to the public transport network, using the Ordnance Survey Centre Alignment of Roads (OSCAR) database, whilst RAILPLAN is used to calculate the time (actual not generalised/weighted) through the public transport network (i.e.

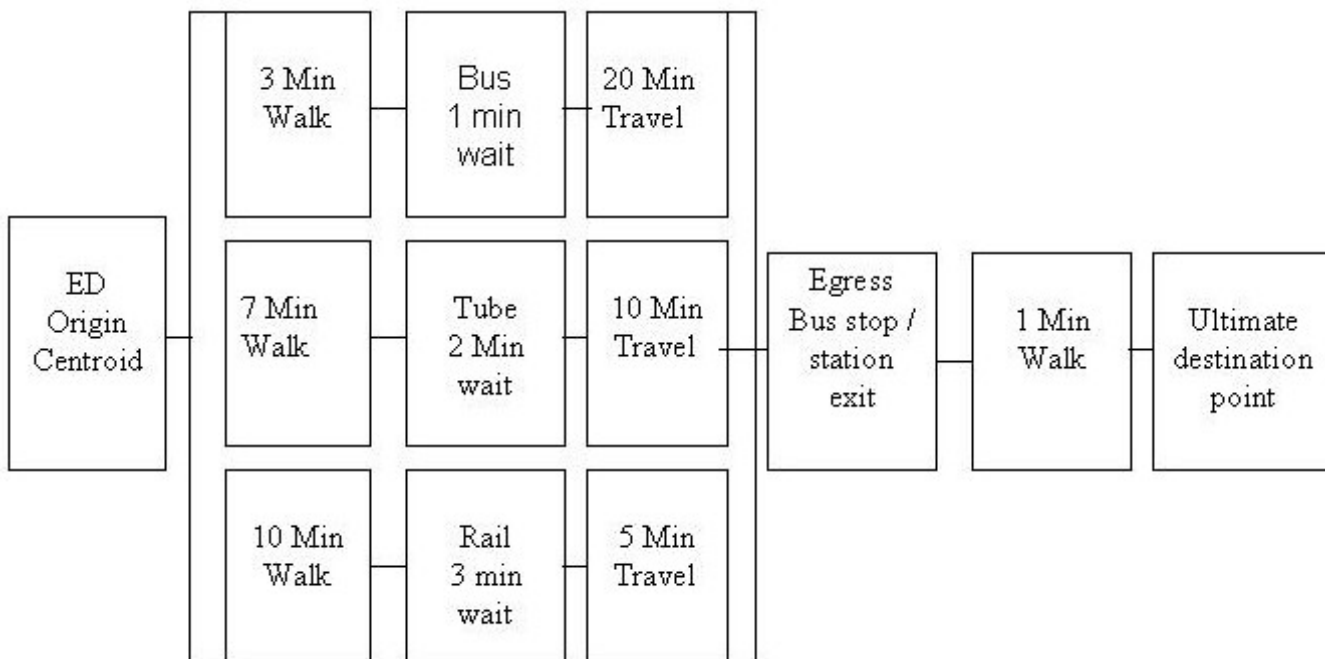
Underground, National Rail, DLR and bus services). All rail stations are modelled within the Greater London area and all station entrances are separately identified. The bus stop locations are based on the Bus Origin and Destination Survey (BODS) definition; these locations do not necessarily correspond to individual bus stops, but tend to represent a pair or group of stops. Overall, there are around 12,000 public transport access points within CAPITAL.

The OSCAR network provides a very detailed representation of the road network in Greater London, including all major and minor roads; this has been supplemented with some additional information on walk links. Distances between the ED and PT Access points, via the OSCAR network, are calculated and are converted to time using an assumed average walk speed of 5kph (which can be globally varied).

RAILPLAN represents stops, links and services together with route attributes such as frequency, which form the network, and uses a multi-routing assignment algorithm. A matrix of trips is assigned to the network and a matrix of travel times is produced. The travel times reflect the quickest route (by any mode) from the PT stops/access points to the selected PT stops/destination points.

For each trip there will be a number of possible routes available if, as in the majority of cases, there are a number of possible points at which the PT network can be accessed. Within London, the nearest PT access point from the trip origin does not always take people to where they need to go, and for some individuals they may have to walk further to access the relevant PT network. In addition, the nearest point may not necessarily provide the quickest overall journey time, as factors such as waiting time, in-vehicle time and interchange time will all affect the overall journey time. It is, therefore, necessary to combine the walk access and PT journey times and then take the minimum of total time. An example of the combined walk/public transport travel time calculation is shown in the Figure 1.

Figure 1: Travel Time Calculation



Example Calculations:

- Route 1: Bus $3+1+20+1 = 25\text{mins}$
- Route 2: Underground $7+2+10+1 = 20\text{mins}$
- Route 3: Rail (minimum overall time) $10+3+5+1 = 19\text{mins}$

The outputs of CAPITAL runs are usually presented as shaded maps showing isochrones of journey travel times, at ED level, to and from a particular location, or set of locations. Displaying travel time information using GIS mapping software means that a detailed description of the PT network and journey times can be clearly demonstrated and easily understood by non-transport individuals. Alternatively, the output file can be fed into a spreadsheet where other types of analysis can be performed.

The strengths of the CAPITAL tool include its ability to calculate shortest time routes between two zones using any combination of public transport modes (i.e. walk, bus, underground, DLR and national rail), and the fact that it incorporates a detailed walk network to bus stops and railway stations. However, limitations include its inability to calculate accessibility for different population groups (other than by using standard values for walk speeds, thresholds, etc.) and to assess accessibility at different times of the day (because it uses only morning peak period data).

3. STRATEGIC LEVEL ACCESSIBILITY TOOL ENHANCEMENTS

The main enhancements made to the two existing strategic accessibility tools during the course of this project are summarised in this section. These were decided on the basis both of the literature review and the findings from the focus groups and depth interviews.

3.1 PTAM: AGREED TOOL ENHANCEMENTS

The main enhancements to PTAM made during the course of the project were as follows:

- Inclusion of the rail network, in addition to the bus network;
- Introduction of a bus/rail and bus/bus interchange function;
- Introduction of a cap on maximum weight times for the first leg of a bus or rail journey;
- Consideration of accessibility at specific times of day associated with access requirements to particular types of facility; and
- Improvements to the presentation of the results using map overlay plots.

Given the uncertainty on METRO's part about how much to invest in upgrading PTAM, until they had assessed the new DfT/MVA Accession tool, most of these enhancements were applied manually to the Keighley area, in order to establish their practicability, and to gauge respondent views regarding these additions.

PTAM uses 400 metre crow fly distances around bus stops, to identify population groups able to reach local bus stops. Rather than attempt to refine this within PTAM – given uncertainties at the time as to whether METRO planned to invest additional resources in the tool – the enhancement of the walk access component of the tool was achieved by developing the new WALC tool, where it was possible to establish the effects of moving to more sophisticated and group-specific measures of walk access.

3.1.1 Making the Enhancements

In the original version of PTAM, there was no cap on maximum weight time at a bus stop, which was simply estimated as being half the bus service headway. It was evident from the interviews with bus users that, for infrequent services, they arrived at their stop some minutes before the scheduled arrival time, and so in areas with lower service frequencies, the uncapped accessibility plots underestimated the places that could be reached within a given time threshold.

Weighting caps were, therefore, introduced for the first leg of bus – and rail – services, as follows:

- Bus services: half the headway, capped at 10 minutes.
- Rail services: half the headway, capped at 5 minutes.

Rail links were added to the public transport network in the north-western part of the METRO area, to cover all journeys within 60 minutes of Keighley station.

In order to represent bus/bus and bus/rail interchange, walk links were added, as follows:

- Between services operating from Keighley bus station: 3 mins;
- Between Keighley railway station and bus services on approach roads: 3 mins;
- Between Keighley railway station and Keighley bus station: 10 mins

Where a person interchanges from one service to another, it is not appropriate to cap both wait times, as they have no control over the length of the timetabled connections. An examination of bus and rail timetables in the Keighley area suggested that services are not timed conveniently with connections in mind, so that the resulting connecting wait times appear to be largely random.

This situation was replicated in the accessibility plots, as follows. The first leg of the journey was capped, as above, and the connecting wait time for the second public transport mode was assumed to be *half the headway of the more frequent service*. The logic for this was that, when connecting from (say) a frequent bus to a less frequent train service, a traveller would be able to choose the last connecting bus service that would arrive before the train was due to depart, and so would not, on average, have to wait at the station for half the headway of the train service; their waiting time would, on average, be half the bus headway. The equivalent logic applies when interchanging between a higher frequency rail service and a lower frequency bus service (as is common in the Keighley area during the evening and on Sundays).

Finally, the presentation of the accessibility plots was improved, to make it simpler for the respondent to locate the area on the map, and by using a consistent set of colour codes.

3.1.2 PTAM Accessibility Plots

Using the updated bus and rail network database, access plots were prepared showing the areas that could be reached within different travel time intervals by public transport from a set of locations, based on 400m crow-fly walk catchments around the bus stops/railway stations. The resulting sets of plots are listed in Table 1. The travel time bands relate either to those proposed nationally by DfT⁸ for the particular activity (where such recommendations exist), or are based on local respondents' views.

Two different types of accessibility runs were carried out: (i) to and from specific locations and (ii) to and from multiple locations (including all those that might be accessed by Keighley residents). The plots were calculated with the relevant wait time cap ON (unless otherwise indicated). The times of day, direction of travel and public transport modes covered by the plots (i.e. bus only, or bus + rail with interchanges) vary according to the type of location, as indicated below:

Table 1: Keighley Accessibility Plots

Location		Mon-Fri Am Peak	Mon-Sat Evening 7pm-11.30pm	Bus only	Bus + Rail	Wait Cap OFF
Specific location	Keighley bus station (no interchange) (15 and 30 minutes)	X (to)	X (from)	X		
	Airedale hospital (with interchange) (30 and 60 minutes)	X (to)	X (from)	X		X
	Bradford Foster Square (with interchange) (30 and 60 minutes)	X (to)	X (from)		X	
	Riddlesden (with interchange) (20 and 40 minutes)	X (from)	X (to)		X	
	Braithwaite (with interchange) (20 and 40 minutes)	X (from)	X (to)		X	
	Highfield (with interchange) (20 and 40 minutes)	X (from)	X (to)		X	
Multiple locations	Larger supermarkets (no interchange) (15 and 30 minutes)	X (to)	X (from)	X		
	Further education (with interchange) (20 and 40 minutes)	X (to)	X (from)		X	

Based on the feedback gained from the first round of focus groups, the chosen order of layers when producing the accessibility plots was as follows, where 1 = base layer and 7 = top layer: (1) topographical layer; (2) urban shading layer; (3) 400m bus stop catchment: longest time band - shortest time band; (4) road network; (5) place names (e.g. Keighley, Steeton, Airedale, Howarth

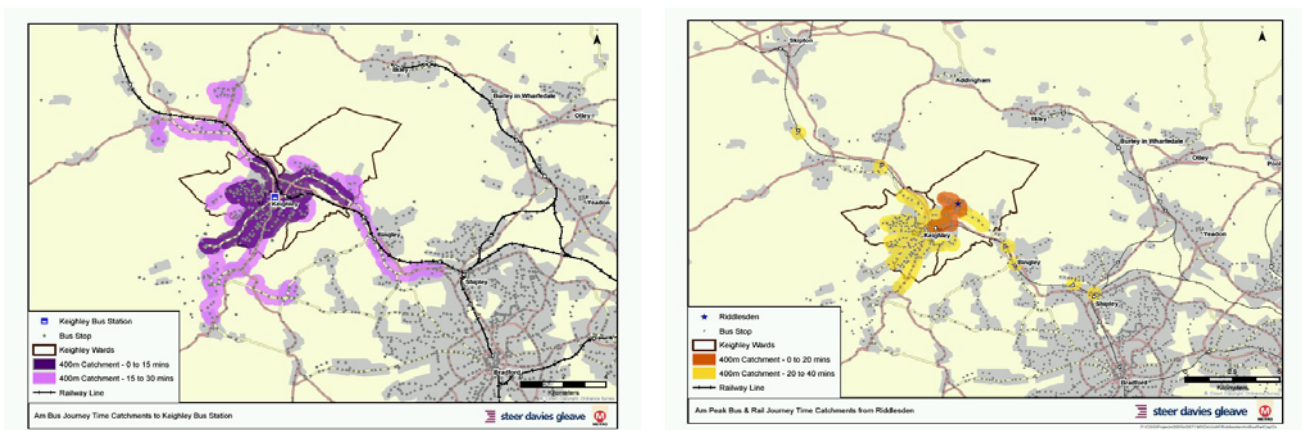
⁸ DfT (2004) Accessibility Planning Guidance, <http://www.accessibilityplanning.gov.uk>

etc); (6) bus stops; and (7) destination landmarks (e.g. 'H' for hospital, 'FE' for further education establishment).

Consistent shades of colour were used to represent the different time bands, as a way of helping the respondents to understand the details in the maps. In order to avoid confusion, shades of either green or blue were not used, as these colours represent rivers/canals, woods/open spaces, etc. As the journey time band increases, the spectrum of colour that is used becomes lighter. The legend accompanying each map highlighted the following: i) bus stops; ii) Keighley wards; iii) 400m catchment; iv) journey time bands; and v) railway lines.

Figures 2 and 3 illustrate the types of outputs produced by the PTAM tool, showing total access times along public transport corridors (shaded according to time band), with standard 400m circles around individual bus stops. Figure 2 shows accessibility (bus only) to Keighley bus station during the morning peak period for two time bands – 0-15 minutes and 16-30 minutes - and Figure 3 shows accessibility (by bus and rail modes, including an interchange function) from Riddlesden during the morning peak period, for two time bands – 0-20 minutes and 21-40 minutes.

Figure 2: PTAM: Access to Keighley Bus Station **Figure 3: PTAM: Access from a residential area**



3.2 CAPITAL TOOL ENHANCEMENTS

3.2.1 Making The Enhancements

The following enhancements were made to the CAPITAL tool:

- Programme in new capability to vary walk access speeds, by person type and area;
- Programme in new capability to vary walk access thresholds (time or distance) to bus stops and stations, by area and person type;
- Indirect incorporation of a cost constraint, by plotting accessibility maps for:
 - (i) One bus route only (no interchange), for a single fare of £1.20;
 - (ii) Bus travel only, for a daily cost of £3.00, and
 - (iii) Travel by all bus and underground/DLR/Rail services in London (here cost of travel ranges between £6.00 peak/£4.70 off-peak for Zones 1 and 2, and £8.00 peak/£5.20 off-peak for Zones 1 to 4);
- Improvements to the presentation of the accessibility plots.

In order to build in this greater flexibility, and at the same time speed up processing, TfL commissioned consultants to reprogram CAPITAL, from being based on ArcView and Network Analyst software, to being based on MapInfo and RouteView software.

Although it would have been desirable to improve walk access representation within the new version of CAPITAL, it was decided that this would add additional complexity to an already

challenging reprogramming task, and might jeopardise its rapid completion. Again, therefore, it was agreed to explore the effects of enhancements to the representation of walk access in the new WALC local access tool.

3.2.2 CAPITAL Accessibility Plots

CAPITAL access plots were prepared showing different travel time intervals by public transport from a specified set of locations, based on 10 minutes walk catchments around bus stops and 15 minute walk catchments around DLR/Underground/National Rail stations. These relatively high catchment values were used in CAPITAL, in order to identify public transport options that might have higher access times, but faster in-vehicle times.

A summary of the accessibility plots that were prepared is shown in Table 2. Plots were prepared for three residential areas and three specific attractions:

- **Specific attractions:** these comprised Stratford interchange, the Royal London Hospital, and Oxford Circus (as representative of the West End of London). Two accessibility maps were prepared from each of these locations, one using the full bus network only, the other including all general public transport modes (i.e. with rail-based services added);
- **Residential locations:** three locations were specified within the Tower Hamlets study area: Fern Street, Stroudley Walk and Brokesley Street.

For each residential area, the following plots were provided:

- 'Spider' bus maps, showing locations that can be reached without a change of bus;
- Full CAPITAL Accessibility maps, bus network only, for time periods of up to 10, 20, 30, 40 and 60 minutes. The maps also show the location of supermarkets, hospitals and workplaces;
- As for (ii), but using the whole public transport network, including rail services;
- Full CAPITAL Accessibility map, bus network only, of the small case study boundary area and a 1km buffer around that area; each map shows the location of GP surgeries and primary schools.

Table 2: Accessibility Plots produced for the Tower Hamlets study area

Location	Mon-Fri Am Peak	Bus + Rail Network	Bus Network Only	Spider Bus Map (£1 fare)
Fern Street	X (from)	X	X	X
Stroudley Walk	X (from)	X	X	X
Brokesley Street	X (from)	X	X	X
Stratford Interchange (20 and 40 minutes)	X (from)	X	X	
Royal London hospital (30 and 60 minutes)	X (from)	X	X	
Oxford Circus (30 and 60 minutes)	X (from)	X	X	

The accessibility plots were based on Monday-Friday am peak periods only, as this is the only time period for which public transport service level data has been coded. The range of public transport modes included (i.e. bus+rail with interchanges, or bus only) vary according to the type of location, as indicated in Table 2.

Based on the feedback gained from the first round of focus groups, the chosen order of layers was as follows, where 1 = base layer and 7 = top layer: (1) topographical layer; (2) urban shading layer; (3) bus stop station catchment: longest time band -> shortest time band; (4) road network; (5) place names; (6) bus stops & stations (names of stations should be clearly marked); (7) destination landmark (e.g. 'H' for hospital, 'PS' for school).

A standard set of colours was used to represent different travel time bands, as follows:

- Up to 10 mins: red;
- 11 - 20 mins: orange;
- 21 - 30 mins: yellow;
- 31 - 40 mins: green;
- 41 - 60 mins: blue

In addition, each map had a legend highlighting the following: Location of origin point; Stations; Ward boundaries; Journey time bands; and Railway lines.

Figures 4 to 7 illustrate some of the outputs from CAPITAL, showing accessibility from a pre-defined bus stop – one of the residential locations - in the Tower Hamlets study area. All the figures relate to the morning peak period. The maps show how accessibility varies according to the set of public transport modes used, reflecting differences in travel costs and interchange requirements.

Figure 4 shows the level of accessibility provided from that bus stop, if travelling is limited to one bus, without interchange (also indicating how far people can travel for a single fare of £1.20). Figures 5 & 6 illustrate the level of accessibility experienced – both locally and London-wide - when a bus interchange function is introduced (showing the distance people can travel for £3 within a given time period), and Figure 7 shows how accessibility improves when all modes of public transport are included within the calculation (cost of travel ranges from £6.00 peak/£4.70 off peak (Zones 1-2) to £8.00/£5.20 (Zones 1-4)). Successive time bands are represented as shaded areas of colour, over the appropriate part of the Greater London area.

Figure 4: CAPITAL: only 1 bus map



Figure 5: CAPITAL: bus interchange map – local area

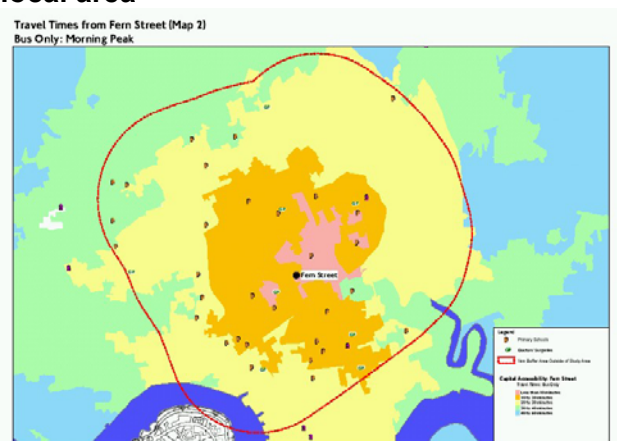
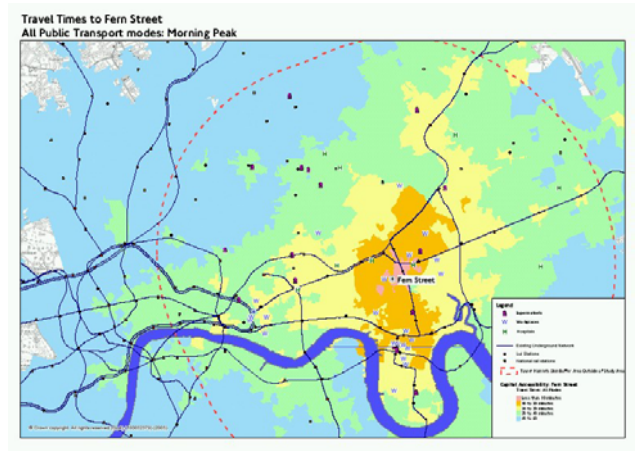
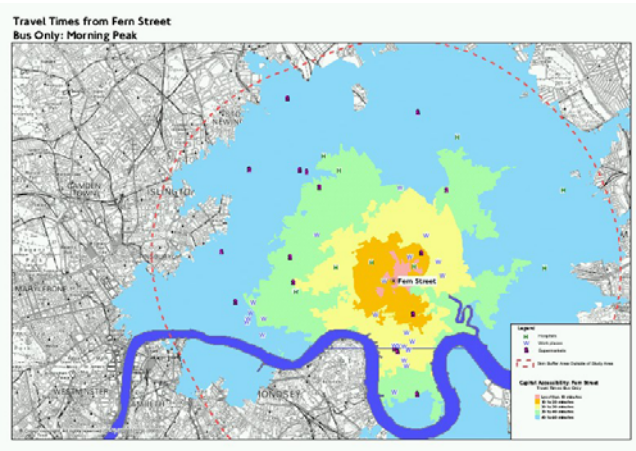


Figure 6: CAPITAL: bus interchange map – larger area

Figure 7: CAPITAL: all modes of public transport



4. THE 'WEIGHTED ACCESS FOR LOCAL CATCHMENTS' TOOL

4.1 LOCAL LEVEL ACCESSIBILITY: THE 'WALC' TOOL

The results of the initial surveys highlighted a number of barriers associated with the local environment and these included:

- (i) The local terrain (e.g. steep hills);
- (ii) The lack of provision of seating and a shelter at bus stops;
- (iii) Difficulties in crossing busy roads, due to speeding traffic, heavy traffic volumes, lack of safe crossing points, and barriers (e.g. guard railing) preventing crossing at convenient points; and
- (iv) Low levels of street lighting.

A detailed pedestrian network was developed, using ArcGIS and ArcView 3.2a software⁹, to better calculate perceived walk access times to bus stops / DLR and underground stations based on the above limitations for different groups of people. The purpose of the tool is to show how standard catchment areas change their shape and shrinks once the impedance effects of different types of barriers on various population groups are taken into account.

4.1.1 Current treatment of walk access in PTAM and CAPITAL accessibility tools

A review of the two strategic accessibility tools showed that a detailed representation of the local walking network (e.g. conditions along the pedestrian route; conditions at the bus stop; gradient; lighting levels or gradient) is not something that is taken into account within either tool. PTAM currently uses straight-line distances to estimate bus stop catchments in its analysis of accessibility, and does not take into account the configuration of the local road or pedestrian networks. Although the CAPITAL model calculates the walk access routes to transport nodes (bus stops and railway stations) along the road network, and contains some network enhancements to reflect pedestrian-only links, it does not include safety concerns or the importance of bus stop seating and shelter, crossings or lighting within its calculations.

4.1.2 Summary of basic approach adopted in developing WALC

The WALC tool is based on a very detailed representation of the local walking network, including pedestrian only routes, short cuts and alleyways. On busy main roads, the footways on each side of the road are represented as separate links (something not available within current OS data). Additional links have been introduced across busy roads to indicate crossing points between the parallel footway links, both at formal crossing points and at regular intervals in between. Using weighted values for steep gradients ($\Rightarrow 1:5$), lack of bus stop facilities (e.g. seating and/or shelter), absence of formal pedestrian crossing arrangements, and low levels of street lighting, the tool is able to produce walk access catchment maps that reflect the concerns of different social groups; catchment areas are also based on different walk speeds (i.e. 2mph for older people and people with mobility problems; 3mph for the 'average' population and 4mph for young people (aged 16-24)) and maximum acceptable walk times to different public transport nodes (i.e. 5 minutes to a bus stop; 8 minutes to a DLR station and 10 minutes to an underground station).

4.2 REPRESENTATION OF THE PEDESTRIAN NETWORK

As mentioned in Section 4.1, the WALC tool seeks to produce local access catchment maps that reflect perceived walk access conditions within a local area. In order to calculate each catchment, the WALC tool requires a number of different types of data:

⁹ Newer versions of ArcView do not support 'Network Analyst' add-in function; MapInfo and RouteView Pro allow for networking but do not allow for individual penalties to be assigned to the road network.

- (i) The location of steep hills; bus stops (and facilities available); crossing points; lamp posts as well as lighting levels (see Section 4.2.2);
- (ii) A road network that includes a detailed pedestrian network (see Section 4.2.3);
- (iii) The weights different groups attach to each of the barriers associated with walk access (see Section 4.3.1); and
- (iv) Other relevant data, including height data (Keighley only) and traffic flow data.

Each of these is discussed in more detail below.

4.2.1 Street Audits

The local authority partners undertook a comprehensive street audit within their relevant local study area (see WP7). The data was captured either electronically, using a hand held GPS tool to record the national grid co-ordinates (as in Keighley), or was manually drawn onto OS base maps and then entered into AutoCAD (Computer Aided Drawing) software (as in Tower Hamlets). The surveyors were asked to collect data on:

- **Bus Stops:** surveyors were asked to plot the location of each bus stop within the case study area and record information about their characteristics (e.g. availability of a shelter, seating, bus timetable information, dedicated lighting, rubbish bin etc) and where people stand to wait for a bus (e.g. on the road, on a pavement (tarmac, flagged stone, cobbles) on a grass verge, etc). The result of the bus stop audit was then compared against existing datasets, held by METRO and TfL, to test their accuracy. The results showed that a relevant part of the TfL dataset was out of date as the bus stops along a particular route within the study area were missing.
- **Crossing:** the location and type of each pedestrian crossing (e.g. zebra, pelican, or junction tables) and central refuges were recorded, as well as the availability of tactile paving at a crossing. Prior to the street audit, this information was not available within the local authority.
- **Guard Railing and Dropped Kerbs:** the location and length of each piece of guard railing was recorded as well as every dropped kerb (Keighley only). Prior to the street audit, this information was not available within the local authority.
- **Lighting data:** the location and type of each lamp post, its height, lamp type (e.g. white or yellow monochromatic light) and wattage (determined from the lamp type (SOX/SON) and the column (lantern) height) was recorded, as well as the type of road (e.g. carriageway or residential area) it is situated on. Prior to the street audit, the local authority lighting departments each held a dataset containing the location of each lamp post and the type of lantern used. The results of the audits were compared against the authorities existing inventories and these were found to be fairly accurate.
- **Luminosity readings:** using light capture equipment, the surveyors recorded the light readings (taken halfway between two posts on a footway) in a small area of Keighley in late evening. The luminosity readings were entered into a GIS model and compared against the results of the local authority light inventory to verify the validity of using wattages as a proxy.

In addition to the street audits, the local authority partners were also able to supply other relevant data, including: traffic flow data; spot-height data; national co-ordinate points for the location and type of traffic accident within each study area; a station audit of DLR and Underground stations in Tower Hamlets) and areas (rather than co-ordinate points) of reported crime (i.e. violence against the person, sexual offences, and robbery of personal property and snatch theft). The traffic flow data acted as a proxy for 'busy roads' and the spot heights were used to calculate different gradients and identify the 'steep' roads.

The other datasets (i.e. accident data, station audit results and areas of reported crime) were used to create a picture of the local study area (e.g. mapping the areas with regard to crime and accident patterns and how these factors can affect residents' quality of life), but they were not directly used in the walk access catchment calculation.

The results of the street audits and additional data (where possible) were then mapped using ArcView GIS 3.2a software onto OS base maps of 1:10,000 for each study area. In the case of Keighley, the data was captured electronically, so it already contained the relevant national co-ordinates and could easily be converted into an ArcView model. However, the results of the Tower Hamlets street audit and accident data were contained within an AutoCAD file and the data had to be converted into an appropriate format before it could be imported into the ArcView model.

4.2.2 Pedestrian network data availability

The majority of models examined in WP3 use either Euclidean distance (as in the case of PTAM) or road centre line data to model the walk route from home or a destination attraction to a transport node. CAPITAL goes one stage further, in that it includes pedestrian-only routes in addition to road centres lines. A number of road centre line data sets are currently available, probably the most common being the Ordnance Survey's OSCAR suite of products (Route manager, Traffic manager and Asset manager), specifically designed for network analysis; Route manager is currently being phased out. Other road centre line data, which can be used for network analysis purposes but was not specifically design for this, includes data from the OS Landline product and Meridian II data. CAPITAL currently makes use of Landline data, whilst PTAM uses Meridian II.

At the time of creating WALC, the second phase of the Ordnance Survey's new MasterMap product – ITN (Integrated Transport Network) - was not available. The ITN is a road centre line data set that includes pedestrian-only tracks and paths – but does not differentiate between footways on each side of the carriageway.

4.2.3 Adding Duplicate Links and Nodes

As mentioned in Section 4.2.2, the lack of a readily available national dataset that includes all relevant pedestrian walk links resulted in the project team having to create its own detailed pedestrian network for each study area. The Ordnance Survey's OSCAR centre line data was used as a starting point.

This only provides one link per road section, and so does not separately represent the footway on each side of the carriageway. On quieter roads it was decided that this was adequate, as people would be able to cross, at will, virtually anywhere along the section, so that significant severance or safety issues would not arise. But on 'busy' roads (defined as having two-way peak period flows in excess of 1,000 vehicles/hour) that inhibit pedestrians crossing the road at any point or time – and where there were sections of guard railing - it was decided to model each footway separately.

In this latter case, it was also necessary to add explicit crossing links across the dual link roads. These were added at all main and side road junctions, adjacent to bus stops, and at recognised pedestrian crossings; where there were gaps of more than 40 metres between these notional crossing points, a new link was inserted between the parallel footway links. In addition, local off-road paths were added, using street maps and local knowledge. A notional walk time was assigned to these pedestrian links across main roads, to take into account of both actual crossing time, and an allowance for delay in crossing¹⁰. The Riddlesdon area of Keighley is separated from the main road bus services by a canal, and where walking routes make use of a canal lock, a value for waiting delay was also added here.

The different types of barrier encountered by pedestrians were next linked to the basic pedestrian network data. Bus stops were identified as destination nodes (as well as underground and DLR stations in London), and details added to reflect the provision of seating and a shelter. In part of Keighley only, sections of road incorporating gradients of 1 in 5 or steeper were identified as being

¹⁰ This is separate from the penalty associated with crossing at unprotected sites, which is added to the basic link walk crossing time.

'steep hills'¹¹, and in both study areas lighting provision along each road section was recorded. As previously noted, in one area of Keighley, detailed luminosity data was also collected, and found to correlate highly with lamp wattage, so the latter could be used as a readily available proxy for lighting levels in both study areas. Sections of 'busy roads' had already been identified, as part of the process of defining dual links.

Values of impedance specific to each population group were then added (see section 4.3), including values for bus stop and road crossing conditions (i.e. crossing where there is no protected crossing along dual link roads), plus link lengths with steep gradients (one area of Keighley only) and different lighting levels. Intermediate weights were applied where provision was partial. Different average walk speeds were assumed for different population groups: i.e. 4mph for young people, 3mph for 'all' and 2mph for older people.

4.3 ESTIMATING WEIGHTING FACTORS

4.3.1 Survey Methodology

One of the primary aims of the bus and DLR/Underground passenger surveys was to identify and quantify the importance of various barriers that people encounter between home and the bus stop or railway station, and at the bus stop itself. This was achieved by providing respondents with a set of pairwise choices, in which the less desirable conditions could be accessed via a fixed walk time from home (i.e. 2 minutes), and the more desirable options involved a walk of longer duration (defined as 3, 5 or 7 minutes, or in some cases longer).

The types of choices respondents were offered covered:

- A short walk to a bus stop up a steep hill, or a longer walk along a flat route (Keighley only).
- A short walk to a bus stop where buses might pass by full, or a longer walk to a stop where it is always possible to board the first bus¹² (Tower Hamlets only).
- A short walk to a bus stop simply offering a marked post, or a longer walk to a bus stop with a shelter and/or seating.
- A short walk to a bus stop/DLR station/Underground involving crossing a busy main road without a pedestrian crossing, or a longer walk via a pedestrian crossing.
- A short walk to a bus stop/DLR station/Underground station along a poorly lit route, or a longer walk along a well lit route (or remaining at home).

These trade-off questions were included in on-street and on-vehicle surveys in parts of Keighley and Tower Hamlets, covering bus, underground and DLR passengers (Tower Hamlets only), and relating to the different types of barriers noted above (see WP4 and WP5). Using median values, weights were calculated for each of the different factors for each social group; in some cases these were represented in the form of fixed time penalty values, while in the other cases they were applied as a scaling factor proportionate to the distance/time involved (see section 4.3.2).

4.3.2 Developing Walk Time Penalties and Ratios

Through a simple tabulation of the data, it is possible to see what proportion of the sample (i.e. total respondents, or a selected sub-group) chooses the shorter or longer option, when offered a particular pair of walk times (e.g. 2 minutes walk up a steep hill [40%], versus 5 minutes walk on the flat [60%]). As would be expected, as the walk time to the 'better' option is increased, the proportion of people choosing that option decreases. There are two ways in which this information

¹¹ This involved creating a 3D surface from OS spot height data, then checking from map contours any areas with steep hills, and finally sampling points along the relevant footway sections to check differences in heights between adjacent points.

¹² This has not been incorporated into WALC, due to the lack of data in London on whether buses can be boarded or not, but it has been identified as an area for further work, at the end of this report.

could be used to quantify the size of the disbenefit that respondents associate with using the less desirable option:

- By estimating the extra walk time as a **time penalty** that a person would be prepared to accept to avoid the less desirable situation; for example, if a person chooses to walk 4 minutes (maximum) to a bus stop with a seat and shelter rather than two minutes to a marked post, then avoiding the post is worth an extra 2 minutes.
- By computing a **ratio of the two walk times**, and applying this as a weighting factor; for example, if a respondent chooses a 4 minute walk along a flat route over a 2 minute walk up a steep hill, then a walk involving a steep hill needs to be weighted by a factor of 2.0, to reflect its effect on route choice.

There are some types of barrier that occur at particular points in the pedestrian network (e.g. the lack of facilities available at a bus stop or crossing a busy road), and others that relate to a whole section of the pedestrian route (e.g. a steep gradient or the level of lighting). Time penalties have been attached to barriers at particular points in the network and ratios have been used along whole sections of a route.

Thus:

Walk time penalty values have been used for:

- Facilities available at bus stops; and
- Crossing a busy road without a pedestrian crossing.

Walk ratios have been applied to:

- Gradient (Keighley only); and
- Lighting conditions along the route.

In some cases, we have also estimated half values, in particular:

- For bus stops, that have either a seat or a shelter, we have applied a half wait time penalty (only applicable in Tower Hamlets – see below).
- For lighting, where an intermediate level of lighting is provided in an area, half the ratio value is applied in these circumstances.

The next issue concerns how to determine the values for the penalties and ratios, since respondents exhibit a range of responses, giving rise to a distribution of values. For simplicity, the trade-off values that have been used are based on the trade-off rate for the mid-point of the population group. That is, the median value at which 50% of the sample opts for the shorter route and 50% for the longer route. However, this 50% split among a population group rarely occurs precisely at one of the trade-off points presented in the questionnaire, so it is necessary to interpolate between values, in order to estimate this point.

This interpolation has been carried out in a very simple way, by taking the nearest known points above and below the 50% level, and using a linear interpolation in between. For example, with the less attractive route taking 2 minutes, at 5 minutes the split may be 60% for the longer route and at 7 minutes it may be 40%. Here the 50% point would lie exactly at 6 minutes, giving:

- A walk time penalty of 4 minutes
- A walk time ratio of 3.0.

NOTE that a **cap** has been placed on these maximum median values, to avoid extrapolating well beyond the range of the options presented in the questionnaire. This was applied as follows:

- Maximum walk time penalty: 8.0 minutes
- Maximum ratio: 5.0

4.4 EMPIRICAL ESTIMATES: KEIGHLEY

In total around 400 people provided trade-off values¹³. The median values for penalties and ratios in Keighley are shown in Table 3. Separate estimates have been made for the Riddlesden residential area (Table 4), which has the steepest hills in the study area, and has the most exposed bus stops.

Table 3: Keighley (overall) estimated penalties and ratios

	Keighley: Overall				
	Seating/Shelter	Gradient	Crossing	Well lit	
	Penalty (mins)	Ratio	Penalty (mins)	Ratio	Half Ratio
All Groups	0.0	1.4	1.0	3.6	2.3
Male	0.0	1.0	0.0	1.2	1.1
Female	0.0	1.7	2.2	4.4	2.7
Young	0.0	1.3	0.0	4.3	2.7
Mid years	0.0	1.2	0.9	3.5	2.3
Older	0.0	2.1	2.3	2.8	1.9
Mobility impaired	0.0	2.1	3.8	2.6	1.8
Able bodied	0.0	1.3	0.4	3.9	2.5
BME	<i>0.0</i>	<i>1.0</i>	<i>0.0</i>	<i>3.0</i>	<i>2.0</i>
Unemployed	<i>0.0</i>	<i>1.5</i>	<i>0.0</i>	<i>2.3</i>	<i>1.7</i>

Note: numbers *in italics* indicate sample sizes of less than 20 respondents

Table 4: Keighley: Riddlesden estimated penalties and ratios

	Keighley: Riddlesden				
	Seating/Shelter	Gradient	Crossing	Well lit	
	Penalty (mins)	Ratio	Penalty (mins)	Ratio	Half Ratio
All Groups	0.0	2.1	2.2	3.4	2.2
Male	<i>0.2</i>	1.9	0.8	1.3	1.2
Female	0.0	2.1	3.0	5.0	3.0
Young	<i>1.0</i>	<i>2.1</i>	<i>1.7</i>	<i>4.0</i>	<i>2.5</i>
Mid years	0.3	1.6	2.0	2.8	1.9
Older	0.0	2.4	2.8	3.5	2.3
Mobility impaired	3.2	2.8	4.5	3.7	2.4
Able bodied	0.0	1.9	1.8	3.3	2.2
BME	<i>0.0</i>	<i>2.0</i>	<i>2.5</i>	<i>3.5</i>	<i>2.3</i>
Unemployed	<i>0.0</i>	<i>1.0</i>	<i>2.0</i>	<i>2.5</i>	<i>1.8</i>

Note: numbers *in italics* indicate sample sizes of less than 20 respondents.

¹³ This number varied from one question to another. See WP4 for further information.

Major differences in values between population sub-groups are summarised below. Statistical tests were carried out to see which of the values were significantly different across the population sub-groups, modes and sub-areas, using the Mann-Whitney U and Kruskal-Wallis tests. Detailed results are provided in Appendix 2.

4.4.1 Gradients (Keighley only)

Unlike other social groups, males, in general, are not willing to walk further to avoid a steep hill. The average ratio is 1.4, with older and mobility restricted people displaying the highest values, with ratios of 2.1. Significant differences in median ratio values were also found amongst the different age groups.

Riddlesden experiences steeper gradients than the other parts of Keighley that were surveyed, and this is reflected in higher ratio values for this sub-group; here the average population value rises to 2.1, and males have an average ratio of 1.9 (versus 1.0 overall), with females showing a smaller rise (from 1.7 to 2.1).

4.4.2 Bus stop conditions

Overall in Keighley, none of the group median walk values in the trade-off exercise exceed 2 minutes, so there are no penalties associated with using a bus stop without a shelter or seating in Table 3. However, when the respondents from the Riddlesden study area were examined separately (being an area more exposed to the elements), it was found that the restricted mobility group had an average walk penalty of 3.2 minutes and male, young and mid-years group had penalties ranging from 0.2 to 1 minute.

Note also that these are **median** penalty values. Even where this is zero, there will be a proportion of the population/group (though less than 50%) who would walk further to obtain better bus stop conditions.

4.4.3 Crossing the road

In Keighley, the average value across population groups was a walk penalty of 1.0 minute, although this masks substantial variations. The median values for males and young people indicate no walk penalties, whilst females, older people and mobility impaired groups have higher values of between 2.2 and 3.8 minutes. Difference between males and females were statistically significant.

Again, penalty values are generally higher in Riddlesden; this time probably associated with higher traffic levels on the nearby main road than in other parts of the study area. Here the average walk penalty across the group was 2.2 minutes. Again there were variations between the groups: the female (3.0 minutes), older (2.8) and restricted mobility (4.5) groups were considerably higher than the average, as opposed to the male (0.8 minutes), young (1.7 minutes) and unrestricted mobility (1.8 minutes) groups.

4.4.4 Lighting levels

Here the trade-off question included multiple responses, including staying at home. In the analysis presented in Tables 3 and 4, only respondents choosing one of the two route options are included, so that they have been re-based to sum to 100%. In Keighley, the ratio values are much higher for lighting than for any of the other factors investigated, with mean ratios of 3.6, compared to 1.4 for gradient and 1.0 for road crossing conditions. Interestingly, in this case, the values for Riddlesden respondents closely match those for Keighley as a whole.

4.5 EMPIRICAL ESTIMATES: TOWER HAMLETS

Around 200 respondents completed the trade-off questions in Tower Hamlets, with roughly equal number of bus, DLR and underground users. The walk time ratios and penalties for each of the modes are shown in Table 5.

Statistical tests were carried out to see which of the vales were significantly different across the population sub-groups, modes and sub-areas, using the Mann-Whitney U and Kruskal-Wallis tests. Detailed results are provided in Appendix 2, and only a brief reference is made here.

Table 5: Tower Hamlets penalties and ratios

	Tower Hamlets											
	Bus						Tube			DLR		
	Board 1 st Bus	Seating/Shelter		Crossing	Well lit		Crossing	Well lit		Crossing	Well lit	
	Penalty (mins)	Penalty (mins)	Half Penalty	Penalty (mins)	Ratio	Half Ratio	Penalty (mins)	Ratio	Half Ratio	Penalty (mins)	Ratio	Half Ratio
All Groups	4.1	1.7	0.9	3.4	4.6	2.8	2.8	4.8	2.9	3.1	4.8	2.9
Male	4.0	1.2	0.6	2.4	3.6	2.3	2.2	3.4	2.2	2.4	4.4	2.7
Female	4.2	2.1	1.1	3.9	5.0	3.0	3.4	5.0	3.0	3.8	5.0	3.0
Young	3.8	1.5	0.8	3.2	4.0	2.5	2.5	5.0	3.0	2.5	5.0	3.0
Mid years	4.2	1.3	0.7	3.0	4.8	2.9	2.7	5.0	3.0	3.2	4.9	3.0
Older	5.5	7.5	3.8	8.0	5.0	3.0	8.0	5.0	3.0	8.0	5.0	3.0
Mobility impaired	3.3	8.0	4.0	3.0	3.9	2.5	8.0	5.0	3.0	3.0	5.0	3.0
Able bodied	4.2	1.6	0.8	3.4	4.6	2.8	2.6	4.9	3.0	3.1	4.8	2.9
BME	4.4	2.1	1.1	3.7	4.6	2.8	3.2	4.8	2.9	3.4	4.8	2.9
Travelling with children	3.3	1.7	0.9	5.8	5.0	3.0	4.0	5.0	3.0	4.3	5.0	3.0

Note: Numbers *in italics* indicate sample sizes of less than 20 respondents

4.5.1 Certainty of boarding first bus (Tower Hamlets only)

There is a high degree of consistency across most groups, with an average walk penalty of 4.1 minutes, indicating the importance people attach to this aspect of bus travel. The exception was the older people group, which had a higher average walk penalty of 5.5 minutes. Due to the absence of datasets containing ‘overcrowding’ figures, it was not possible to include the inability to board the first bus figures within the walk access calculations.

4.5.2 Bus stop conditions

In Tower Hamlets, all the groups had a penalty of at least 1 minute, with average population values producing a walk penalty of 1.7 minutes. Males are substantially below this average value, while older people and the mobility impaired a well above (walk penalties of 7.5 and 8.0 minutes) – though both sample sizes are small. This suggests a much greater sensitivity to bus stop conditions in Tower Hamlets than in Keighley, and is probably associated with higher levels of expectation in an inner metropolitan area.

4.5.3 Crossing the road

For Tower Hamlets, separate values are shown for those accessing bus stops, DLR stations and underground stations. Although generally the average walk penalties for those travelling by bus are slightly higher than for the rail-based modes (i.e. 3.4 minute penalty versus 2.8 min. for underground and 3.1 min. for DLR), overall the pattern of variation among the population subgroups is similar.

Males have the lowest values, and females, older people and the mobility impaired have higher ones. Differences are statistically significant between the values for males and females, different age groups and those with/without restricted mobility. The extra distances that people said they would be prepared to walk to access a pedestrian crossing were generally much higher in Tower Hamlets than in Keighley, perhaps reflecting the greater traffic flows on main roads in the former study area.

4.5.4 Lighting levels

As was found in Keighley, the trade-off values for Tower Hamlets also are greatest in the case of lighting. They are higher than for Keighley, and for around half the groups they exceeded the capped values of a ratio of 5.0. Males consistently displayed the lowest values. The only statistically significant differences are between BME and non-BME groups.

4.6 APPLYING THE WEIGHTING FACTORS

4.6.1 Crossing

Using the traffic flow count data that was supplied by the local authority, the roads within each local area were categorised as either: 'busy main' or 'residential', with the latter being fairly quiet. For West Yorkshire, 'busy' roads were selected on the basis of more than 1,000 vehicles travelling along a road during a peak period (e.g. inbound morning peak (07.30-09.30); inbound inter peak (14.00-15.00); outbound inter peak (15.00-16.00) and outbound evening peak (16.00-18.00). In Tower Hamlets, a 'busy' road was selected if the vehicle count data was more than 1,000 vehicles per hour, on average, during the working day..

Using ArcView and Arc GIS 3.2a software, duplicate links were added to the road network (along 'busy' roads) to enable two types of 'crossings' to be added to the road network: 'formal' crossings (zebra, pelican and junction tables) as well as 'dummy' crossings - where there is not an actual crossing near a bus stop or at a junction along a busy road.

As previously noted, crossing walk/wait times were applied to all crossing points and, in addition, appropriate penalties for each social group were then added to each 'dummy' crossing point.

4.6.2 Gradient

First using the contour lines on detailed OS maps to identify candidate sections of road with possible steep hills, these were then examined in more detail by checking height data at specific points, as interpolated from spot height data. In this way it was possible to identify those sections of roads (in Riddlesden only) where the gradient is steeper or equal to 1 in 5. Gradient penalties were then applied to all sections of a road that qualified as being steep, whether the walk to the bus stop was up or down hill.

4.6.3 Lighting

Lighting impedances were grouped in different ways, depending on the lighting provided in each area. Thus, Riddlesden only had two groups for lighting: good and poor lighting levels; whereas Braithwaite and Tower Hamlets had three groups: good, medium and bad lighting levels. These were determined based the 'lux' and 'wattage' data supplied by the Local Authority lighting departments:

- **Riddlesden** was given two levels of lighting: good (which was assigned to the doubled linked road (busy road) (100Watts-150W) and the rest of the Riddlesden area was assigned poor lighting (35W-90W),
- **Braithwaite** lighting was grouped into three levels: Good lighting (150W-100W), medium lighting (90W-55W) and poor lighting (50W-35W).
- **Tower Hamlets** also had three lighting levels: Good (category 2/1: 15-25 lux), medium (category 2/2: 10-20 lux) and poor lighting (category 2/3: less than 10 lux).

In the case of Braithwaite and Tower Hamlets, a full penalty was given to all those roads that were considered as being 'poorly' lit and a half penalty was attached to those roads with 'medium' lighting. For Riddlesden, a full penalty was attached to all poorly lit roads.

4.6.4 Bus Stop Conditions

Using the results of the street audits, and ArcView and Arc GIS 3.2a software, it was possible to map the location of each bus stop and the facilities (e.g. seating and/or a shelter) available. A full penalty was applied to those stops without any facilities and a half penalty was given to those stops with just one of the two facilities.

5. ACCESSIBILITY MAPS

5.1 'WALC' OUTPUT MAPS

Once the various weighting factors had been applied to the pedestrian network and, where appropriate, to certain bus stops, maps were created to show how the catchment sizes vary by type of social group. Three different types of catchment area were calculated for each of the socially disadvantaged groups covered in this study, to/from selected bus stops and railway stations, based on the following equations:

- Catchment 1: Unadjusted walk catchments - no penalties
 - Riddlesden: *walk time + road crossing walk/wait time + canal lock walk/wait time*
 - Braithwaite and Tower Hamlets: *walk time + road crossing walk/wait time*
- Catchment 2: Daytime penalties
 - Riddlesden: *walk time + road crossing walk/wait time + canal lock walk/wait time + (gradient walk time x gradient penalty – gradient walk time) + unprotected crossing penalty + bus stop penalty*
 - Braithwaite and Tower Hamlets: *walk time + road crossing walk/wait time + unprotected crossing penalty + bus stop penalty*
- Catchment 3: Night time penalties
 - Riddlesden: *(walk time x lighting penalty) + road crossing walk/wait time + canal lock walk/wait time + (gradient walk time x gradient penalty – gradient walk time) + unprotected crossing penalty + bus stop penalty*
 - Braithwaite and Tower Hamlets: *(walk time x lighting penalty) + road crossing walk/wait time + unprotected crossing penalty + bus stop penalty*

The Catchment 1 bus stop maps are based on unweighted 5-minute (400 metre) crow fly catchment areas, shown as circles; the unadjusted catchment areas around each DLR and underground station are slightly larger, based on an 8-minute (640m) and a 10 minute (850m) radius, respectively¹⁴.

Different walk speeds have been assumed for different population groups. For example, 4mph for young people; 3 mph for the 'average' member of the population, and 2mph for older people and people with a mobility impairment.

The three different catchment area maps are layered on top of one another in Figures 8 to 11, using the following colour coding convention:

- The green layer shows the simple, unweighted Catchment area 1, superimposed on the pedestrian network, without any weights attached (although using footway rather than crow fly distances);
- The amber layer shows the smaller size of the daytime weighted Catchment 2 area (reflecting weights associated with road crossing conditions, bus stop conditions and - in the case of Riddlesden in Keighley – gradients of more than or equal to 1 in 5);
- The red layer shows the size of the smallest night time Catchment 3 area, when daytime weightings plus appropriate lighting impedance values are included in the routing calculations.

For comparison, Figure 8 also shows the standard 400 metre crow fly, unweighted bus stop catchment area boundary currently used in PTAM, as applied to a bus stop in Riddlesden.

¹⁴ The catchment areas are primarily based on acceptable threshold values for walk access times. So, as walking speeds increase or decrease, the radius of the catchment area, in metres, also increases or decreases, respectively. The distances shown here in parentheses are based on an assumed average walk speed of 3 mph.

Figure 8: WALC outputs: Average Population in Keighley

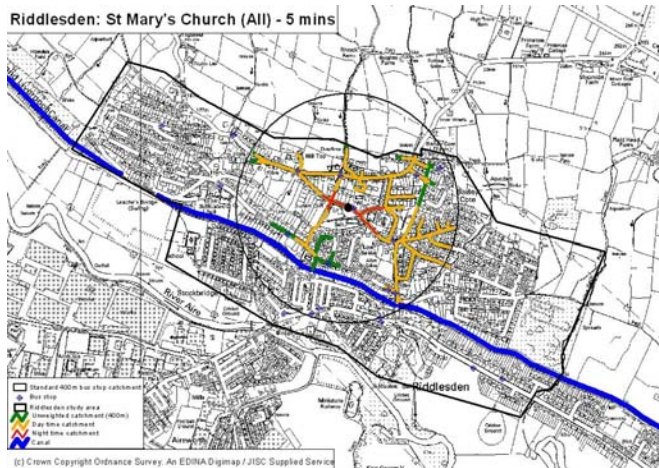


Figure 9: WALC outputs: Older People in Keighley

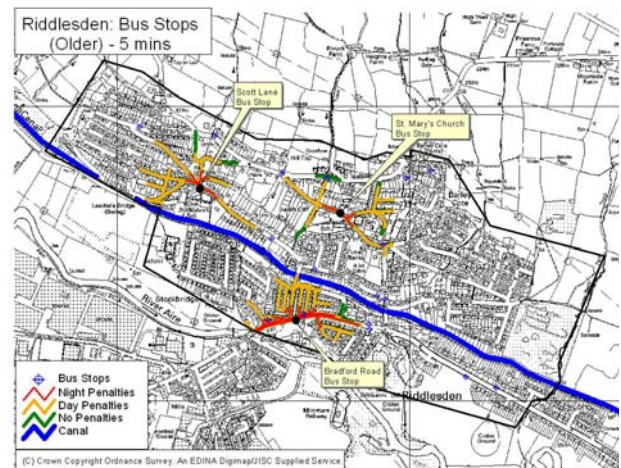


Figure 10: WALC outputs: Average population in Tower Hamlets

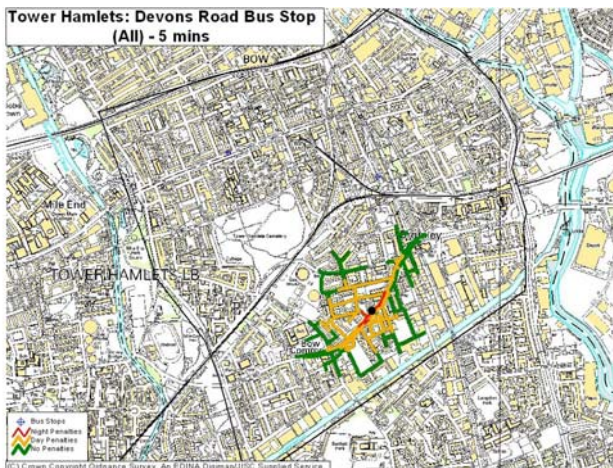
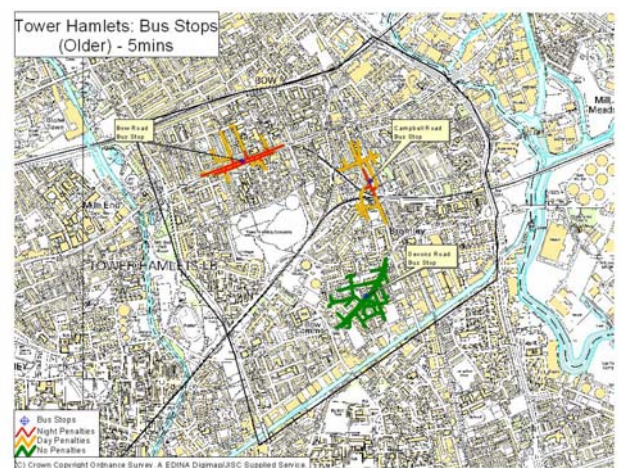


Figure 11: WALC outputs: Older People in Tower Hamlets



The four figures each display the three Catchment area types, using average population values (Figures 8 and 10), and values for older people (Figures 9 and 11), in both Keighley and Tower Hamlets. These values include both the appropriate time penalty and ratio values, plus the different assumed average walk speeds. All four maps show bus stop catchment areas, for ease of comparison; however, in the case of Tower Hamlets, a range of catchment maps around underground and DLR stations have also been prepared.

As can be seen, the catchment sizes for older people are generally much smaller than for the population average, due to slower walk speeds. Also, except along well lit main roads, night time catchment layers (in red) are much smaller than the daytime (amber) layers. In the case of the Devons Road (Figure 11), which lacks both seating and shelter, the high penalty attached to poor bus stop provision among older people means that the catchment area shrinks to zero, once penalties are applied.

5.2 VALIDATION OF OUTPUTS

The outputs of the new WALG tool and the modified strategic accessibility tools were then presented to respondents in the two case study areas. This was done in focus groups comprising representatives of selected social groups, using examples of outputs relevant to their particular

activity and travel needs. To validate the results of the tools, groups were asked about their comprehension of the maps, and to compare the strategic and WALC tool outputs with their own perceptions of accessibility to/from and within their local area (see WP7).

Participants across all groups showed a clear understanding of the purpose and content of all the strategic and local accessibility maps, and found them to be comprehensible, relevant and useful. The groups supported the WALC tool's assumption of an unweighted 5 minutes walk time to a bus stop, 8 minutes to a DLR station, or 10 minutes to an underground station, and the approach that had been used for calculating weighted accessibility by type of barrier.

Questions were raised, however, about:

- The assumed walk speeds; in particular, young people regarded the assumption that they would walk at an average speed of 4mph as being too high;
- About the failure to take full account of the impacts of service reliability (including the inability on some occasions to be able to board the first vehicle¹⁵); and
- Some bus connecting times at interchanges were regarded as being unrealistic.

This suggested the need to adjust some parameter values in the accessibility tools. The validation process has also provided the local authorities with a rich source of data about the concerns of local people living in the area.

¹⁵ This concern had been identified during the previous focus group research, particularly in Tower Hamlets, and trade-off data on this topic was collected in the self-completion questionnaires. However, Transport for London does not have the necessary objective data from which this can be added to the walk access maps.

6. RECOMMENDED FURTHER WORK

Several areas for further investigation suggest themselves as a result of the work carried out in this project.

6.1 STRATEGIC ACCESSIBILITY TOOLS

6.1.1 Addition of boarding capacity constraint

The focus groups and in-depth interviews indicated that, particularly in London, people can experience problems in trying to board the first bus, if they are in a wheelchair or have a shopping trolley or a child in a buggy. Such problems were reported – and observed – during both peak and off-peak periods in the study area in Tower Hamlets. We were only able to test the importance of this factor indirectly, by including it as one of our walk trade-off questions in the London survey, where it attracted a high score.

The current TfL measure of service reliability is based on excess wait time, but *this assumes that* the traveller is able to board the first bus that arrives. To the extent that this is not the case for some disadvantaged groups, then the difficulties that they face in using the bus system are underestimated using current performance indicators. In addition, the information contained in existing accessibility maps, which are based on the assumption that people can board the first vehicle, is inaccurate for some groups of people. For example, maps showing journey travel times for people travelling with young children in pushchairs from a residential area to a hospital during the morning peak period will be misleading unless a ‘boarding denial’ penalty is included within the calculation.

From a research perspective, this raises two questions. First, how to measure the extent of bus boarding ‘denials’ as part of regular service monitoring and, second, how to include this as part of a measure of accessibility.

It is clearly not practical to derive an indicator through direct measurement, mainly because of the scale of the task that would be required across London, but also because of the difficulty of assessing - while on a bus - whether a person is attempting to board that particular bus. What would probably be required would be to use existing monitoring data to estimate average bus loadings, along sections of route and for particular time periods, and then estimate probability distributions of boarding denial for specific person types, based on a combination of observation and experimentation at particular bus stops and for different vehicle types.

The second issue is how to incorporate this into an overall accessibility measure. The simplest solution would be as an addition to the average waiting time at the bus stop, but this may underestimate the true significance of this factor in affecting perceived accessibility. For example, rather than using average additional wait time across all potential journeys, a better reflection of impact might be obtained by taking a value derived from – say – the worst 20% of bus journeys.

6.1.2 Adoption of weighted travel times

The simplest accessibility tools add together all the components of travel time (i.e. walk, wait and in-vehicle) and plot the envelope of locations that can be reached from a given starting point within a given time threshold (e.g. 60 minutes).

The more advanced tools take into account the declining attractiveness of potential destinations with increasing distance (i.e. time) from an origin point, by using a distance decay measure (e.g. Hansen measure). However, this only weights overall journey time, from door to door, and still gives each component of journey time equal weight in calculating the total travel time.

The argument for applying a distance decay function is partly based on logic, but also on empirical evidence, and it is the latter that is used to calibrate the function. However, empirical evidence also suggests that time spent walking or waiting for public transport is weighted more highly (i.e. is less attractive) than time spent in vehicle, yet this is *not* currently taken into account in the accessibility tools. This greater disutility can be viewed just as a weighting reflecting less comfortable conditions, but there is also evidence to suggest that travel times are actually perceived to be longer than they actually are by roughly the size of the empirical weighting – strengthening the case for including this within accessibility measures.

Weights would need to be estimated for different population groups, from which it would be possible to display ‘generalised’ time¹⁶ plots – as has been incorporated in the development of the ‘WALC’ tool within this project. These might be expressed, for example, as 30 minutes subjective time contours (with or without a Hansen weighting). There is some support for adopting this approach from the follow up interviews (WP7), where under some conditions people’s perceptions of time contours differ from those derived from objective travel time data. In multi-modal tools, such as CAPITAL, the effect would be to increase the relative attractiveness of modes that require shorter walk and wait times relative to in-vehicle times – which, in many situations, would favour buses.

6.1.3 Relating access to demand

One of the limitations of accessibility planning tools, as opposed to transport/land use models, is that the former do not give any indication of changes in demand that might result from an improvement – or deterioration – in accessibility in an area.

Without developing a full-blown, demand modelling module for accessibility planning tools, it would be useful to explore whether simple elasticity estimates could be derived for unit changes in accessibility – within certain bounds. The task might be considerably simplified if objective travel times were replaced by the subjective time measures proposed above. However, in order to operationalise the approach, it requires that local data is available on existing levels of demand, which may be a problem in some parts of the country.

6.2 ‘WALC’ TOOL

6.2.1 Measuring walk speeds

The use of subjective/weighted walk times in the new WALC walk access tool seemed to be easily comprehended and well received by respondents, but one area of particular contention was with regard to the average walk speeds for different population groups that were assumed when the accessibility plots were prepared. For example, young people in Keighley argued that their walking speeds had been significantly overestimated.

There appears to be very little empirical evidence in the literature on average speeds for different population groups, and this would be worth further investigation.

¹⁶ Note that we do not advocate taking this a stage further, and using generalised cost (i.e. time + cost), since people have separate time and money budgets, which may only be tradeable, to a limited extent, particularly among disadvantaged population groups.

APPENDICES

APPENDIX 1: OPTIONS FOR CREATING DETAILED WALK ACCESS NETWORKS

Following a series of brainstorming sessions among TSG staff, and discussions with TfL and InfoTech (the providers of the RouteView software, which CAPITAL will be utilising for its network calculations), a number of approaches were identified. These are presented below, along with a **SWOT** (Strengths/ Weaknesses/Opportunities/Threats) analysis of each.

The approaches outlined are not mutually exclusive and it may be that a combination of approaches will provide the best solution. These are discussed separately, first for links and then for nodes, and this is followed by a brief assessment of the preferred combination(s).

LINKS

Approach L1:

The first approach would be to generate a detailed pedestrian network (e.g. including footways on both sides of a carriageway), by extracting the data representing kerb lines from OS MasterMap or Landline data sets. Figure 1 gives a graphical representation of what a pedestrian network produced in this manner might look like.

Pedestrian only routes and crossings, as well as non-metal-edged sections of road, would need to be added by hand to the extracted data, whilst some kerb lines where there is no pavement (merely a grass verge) may need to be removed from the network.

Figure 1: A graphical representation of approach L1

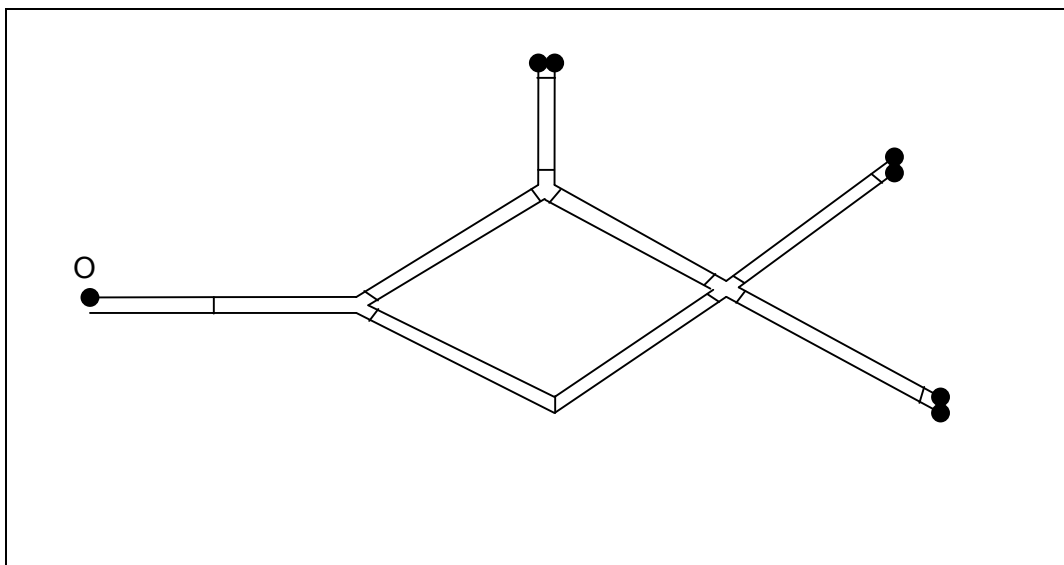
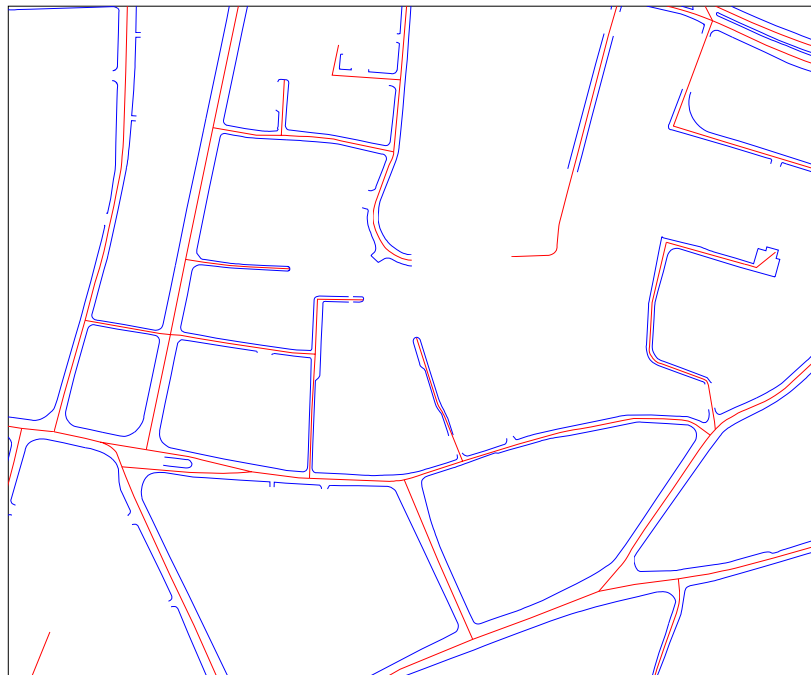


Figure 2 shows an extract from the OS Landline database, with kerb lines shown in blue and road centre lines in red.

Figure 2: kerb lines and road centre lines extracted from OS landline data



ASSESSMENT:

- S:** This approach is particularly well suited to representing network conditions as experienced by pedestrians.
- W:** Pavement edges may not represent pedestrian routes effectively, particularly where the pavement extends between parking bays, or where the pedestrian area is very wide, for example in public squares (see Figure 3).

Figure 3: Illustrating problem associated with wide pedestrian areas and unusual shaped pedestrian areas



- O:** This solution offers the possibility of building up a very detailed pedestrian network over time. The method could be used by someone who is not an expert at programming or at using GIS software.
- T:** It may prove to be time consuming to edit in/out those features which are either not included or incorrectly coded within MasterMap. There is also a possibility of small gaps in the network being created through editing errors, which will have a major effect on shortest path analysis.

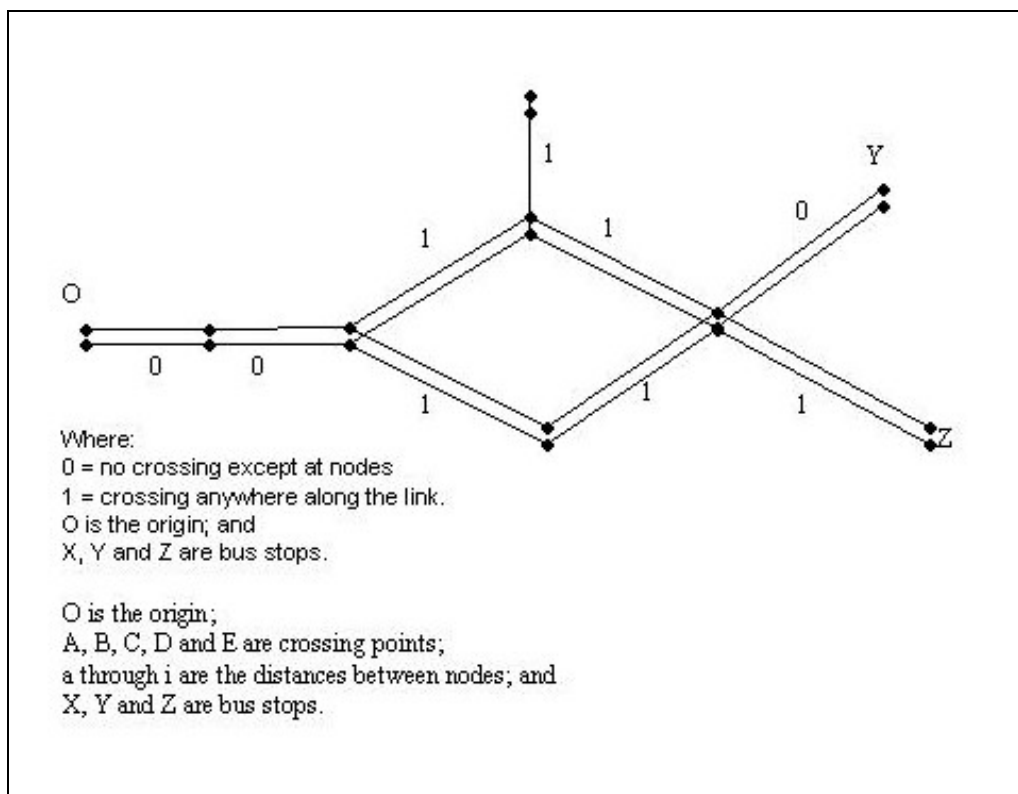
Approach L2:

Replicate footway conditions by editing the network file of road centre line data, so that every link is duplicated. Assign each link an identifier. For links where crossing the road can occur at any point, without any significant impedance, then assign the two parallel links the same identifier. Otherwise, assign different identifiers and only permit crossing at nodal points.

ASSESSMENT:

- S:** Allows a good representation of crossing habits, particularly on side and residential roads where crossing tends to take place anywhere along the length of the road, and light traffic volumes represent only a slight impedance to crossing movement.
- W:** It is extremely doubtful whether RouteView could deal with this level of sophistication in its network analysis; ArcView's Network Analyst certainly cannot. ESRI's NetEngine developers' library does have the facility to prevent interchange between links on different levels; however, interchange in network routing algorithms can usually only occur at nodes, so it may be necessary to divide links which can be crossed anywhere along their length into a number of very small segments.

Figure 4: A graphical representation of approach L2

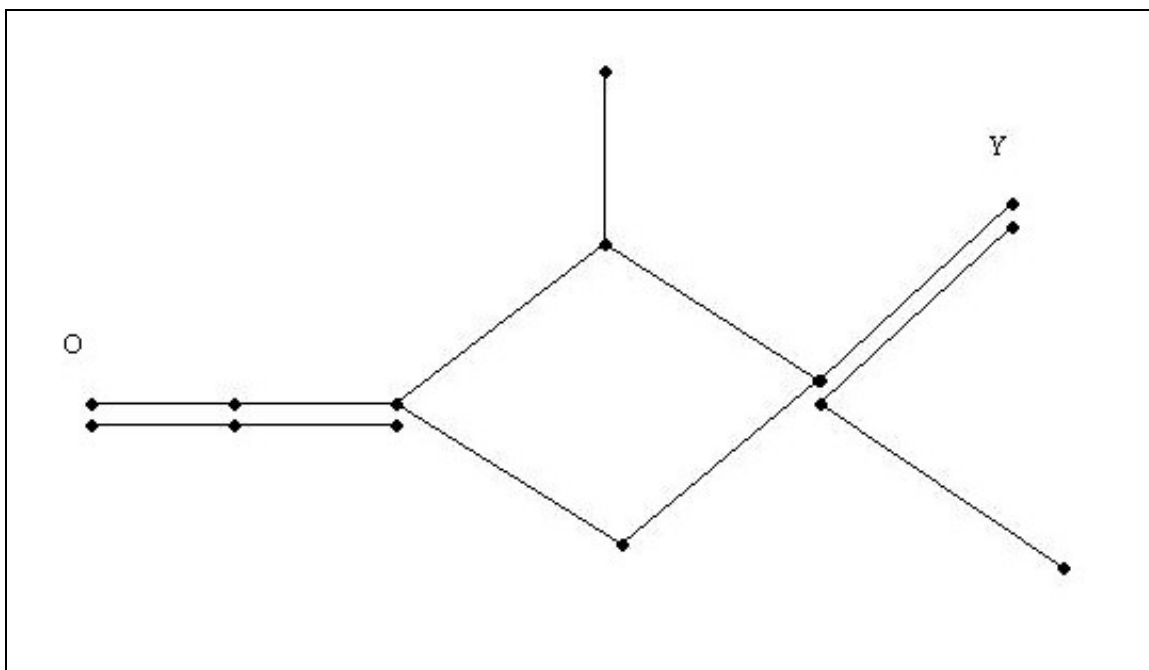


- O:** If this could be achieved without the necessity of dividing links into large numbers of very small segments to imitate unlimited crossing points, then this would be a step forward in the science of network analysis and routing.
- T:** This is a very innovative approach and possibly cannot be achieved using current network analysis/routing algorithms. It thus could involve considerable time and resources to implement.

Approach L3:

Edit the network file in such a way that each section of road along which barriers or traffic flows prevent pedestrians from crossing is duplicated, having two links (to represent each footpath separately). This will allow crossing along these links to only occur at nodes (junctions and specified crossing points).

Figure 5: A graphical representation of approach L3



In other cases, where there are no impediments to crossing at any point along the section of road, just represent this section as one link.

ASSESSMENT:

- S:** Allows a good representation of crossing habits, particularly on side and residential roads where traffic volumes are light and crossing tends to take place anywhere along the length of the road.
- W:** Does not allow for time delays in crossing sections of road marked as single links.
- O:** Conceptually very simple.
- T:** Difficult to automate a process where only a selection of links needs to be duplicated.

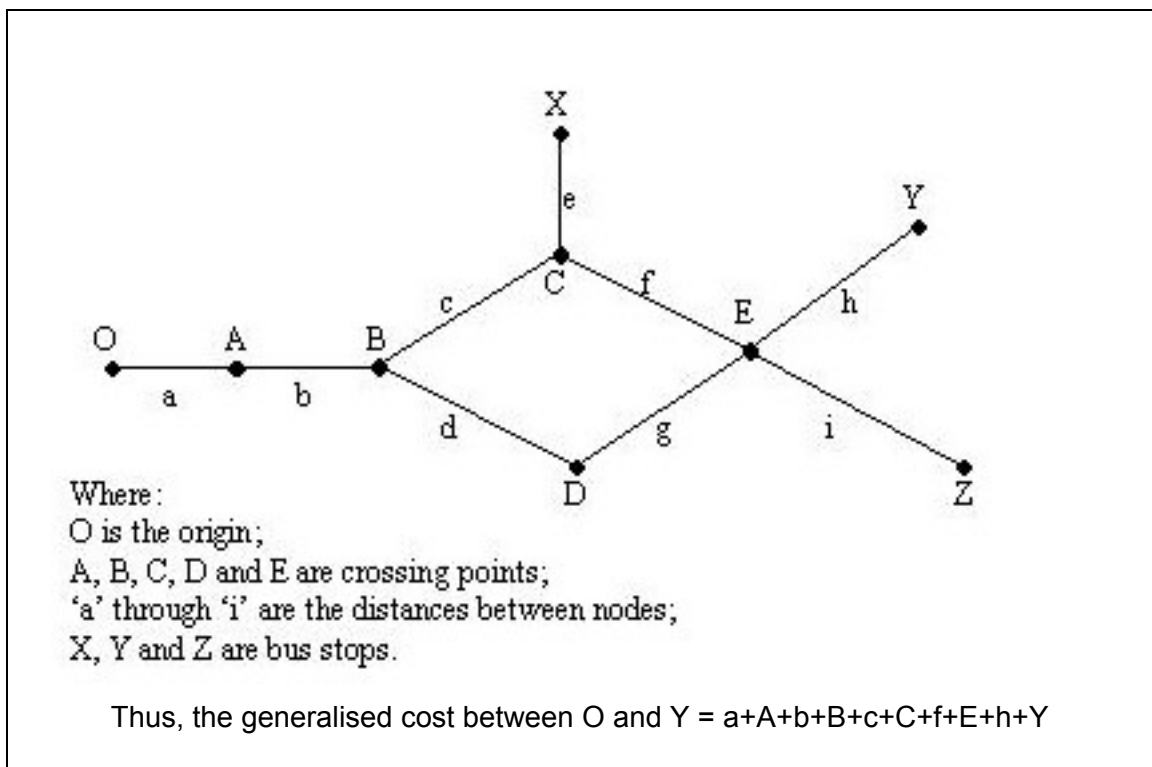
NODES

This deals particularly with representing conditions at junctions, crossing points and bus stops.

Approach N1

This approach involves adding penalties to the nodal points in the network, to reflect penalties associated with crossing the road at junctions. Additional nodes could be inserted, to represent conditions at marked pedestrian crossing points (but see reservation below), and to represent bus stops (where impedances could be added to reflect the kinds of facilities provided there).

Figure 6: A graphical representation of approach N1



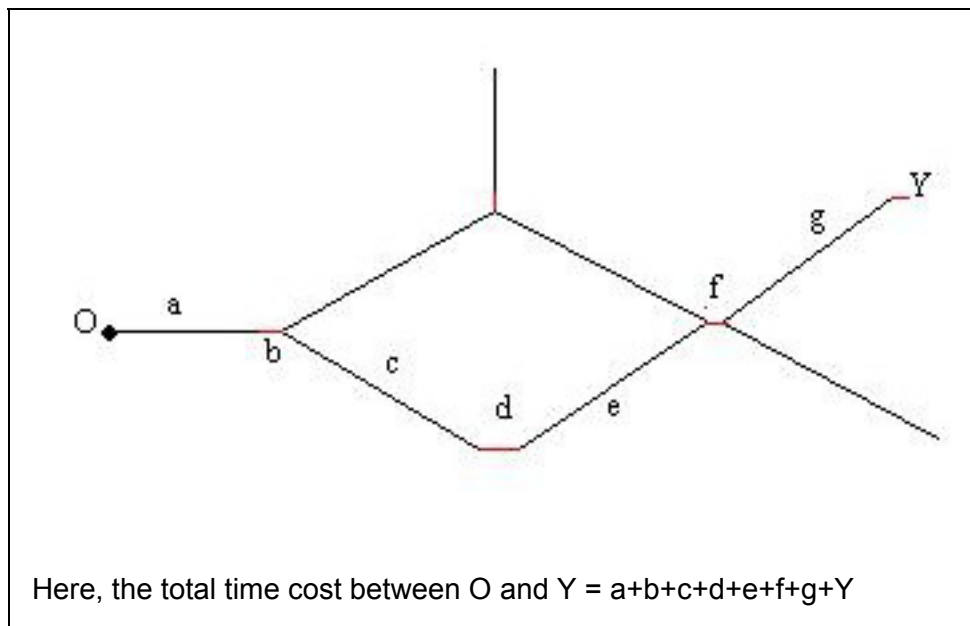
ASSESSMENT:

- S:** This approach is well suited to representing conditions at cross roads and at bus stops, where it could take into account the provision of a shelter, lighting and seating.
- W:** It deals poorly with issues related to most types of road crossing, however, as each road segment is only represented by the road centre line. Crossing penalties could be added in by creating nodes at appropriate points to represent formal crossing places; however, the crossing penalties would be counted each time a node is encountered, whether or not the road is actually crossed, which could lead to inflated time penalties on certain routes.
- O:** If nodes could be given different characteristics (e.g. to represent walk/bus interchange), then this approach may lead towards a solution to the problem of limiting the number of interchanges allowed on public transport.
- T:** The routing software used in CAPITAL (was ArcView Network Analyst, now RouteView) does not explicitly include nodes in its calculations of shortest paths, and no attributes can be assigned to points at which links meet. It may be difficult to find routing software with this capability.

Approach N2:

The problem of the inability of routing software to deal with node impedances identified in approach N1 could be overcome by replacing nodes with zero length lines, with an attribute of time attached to each. These zero length lines would then be included in any network analysis that uses the attribute of time to calculate the routes. Figure 7 illustrates this idea, where the red inserts represent the zero length lines.

Figure 7: A graphical representation of approach N2



ASSESSMENT:

- S:** This approach is also well suited to represent conditions at bus stops, and at road junctions, and has the potential advantage of allowing for different penalties for moving between specific pairs of arms at a junction.
- W:** There are a number of issues to resolve with regards to how to deal with more complex nodes where 3 or more links join and whether it would be practical to allow for left and right turns (depending on the direction of the movement) to be assigned different penalties. As for approach N1, crossing points away from junctions could be added in by creating nodes (zero length links) at appropriate points; however, again, the crossing penalties would be counted each time that link is encountered, which may lead to inflated penalties for certain routes.
- O:** This may also lead towards a solution to the problem of limiting the number of interchanges allowed on public transport.
- T:** Editing a network file in this way is difficult. It is unlikely that the standard functions available in packages like ArcView and MapInfo would be capable of performing this task. The process would need to be automated and could only really be undertaken by an expert in GIS/programming, who understands in detail the file structures of the network being manipulated.

Non-Network Solution for Bus Stop Penalties

Bus stop penalties could be incorporated, not by changing the network representation per se, but by adding an extra stage in the process of calculating the distance to the bus stop. The distance (or time) to the bus stop would be calculated as currently using routing software (i.e. network

analyst, RouteView). The distances to each bus stop could then be passed to another programme, which would add the time equivalent penalty for that bus stop to calculate new total times to each bus stop. These adjusted times would then be passed to the part of the model which deals with on-board routing calculations.

Suggested algorithm:

Time to bus stop = shortest path along network (calculated using RouteView etc.)
Total time cost of travel to bus stop = time to bus stop + bus stop attribute penalty.

This could be done by using RouteView (or equivalent software) to generate and output the distance to each bus stop. A short function (in Visual Basic) would then use this output to calculate the generalised cost of travel to each bus stop. This would then be fed back into CAPITAL (for example) for the calculations of total travel time for the whole journey.

ASSESSMENT:

- S:** This could be a relatively simple solution to implement.
- W:** It only deals with bus stop conditions
- O:** It provides the potential for adding in increasing levels of sophistication without the need to rebuild the entire programme each time.
- T:** It could create extra problems, as it adds an extra layer of complexity to the model structure.

Combined Solutions

Any comprehensive solution is likely to involve some combination of link enhancement and node recognition.

Some combination/compromise of Approaches L2 and L3 appears to offer the best representation of the links on the network. While a section of road with no impediments to crossing at any point is best represented by a single link (in effect, implying that the section operates as though the footway extends across the full width of the road), for reasons noted under N1, this only really works where all junctions are cross roads (and have the same treatment – e.g. dropped kerbs – on parallel arms); otherwise, each footway needs to be represented separately, to account for the different crossing conditions experienced at side roads or crossovers.

Given the problems of finding standard routing software that directly takes into account nodal characteristics, this would suggest that option N2 (building in dummy links) is probably the best solution. This could accommodate not only varying junction and pedestrian crossing characteristics, but also differences in the provision of facilities at bus stops.

APPENDIX 2: STATISTICAL DIFFERENCES IN WEIGHTS BY GROUP

KEIGHLEY

NOTE: THE SUB-AREA SUB-GROUP SAMPLE SIZES VARY GREATLY, AND SOME ARE VERY SMALL

(e.g. Braithwaite lighting ratios based on samples of N=9 for restricted mobility and N=81 for unrestricted mobility). The majority of sub-sample sizes are under 20.

Table 1 shows the analysis of differences in Keighley, which was grouped into Braithwaite and Riddlesden, and 'overall' (i.e. all those that live in Keighley, including outside the two areas).

The results of the 'overall' category show that there is a significant difference of 'point of change' between male and female for the choice of 'crossing a busy road without an official crossing and walking further to an official crossing' (p=0.046).

The 'point of change' values for walking up a steep hill or walking further along a flat route varied significantly between age groups: 16-24 years, 24-59 years and 60+ years (p=0.004).

Residential location played a significant role in some cases:

- Braithwaite - The choice of walking up a steep hill or walking further along a flat route varied significantly between those that have restricted mobility and those that have unrestricted mobility (p=0.025).
- Riddlesden - The time people are prepared to walk along a well lit road as apposed to walking a shorter distance along a poorly lit road differed significantly between male and females (p=0.039).

Table 1: Significant difference in 'point of change' between groups (p-value) †

	Avoid walking up a steep hill			Prefer a bus stop with seating/shelter			Avoid crossing busy road			Prefer well lit route		
	Braithwaite	Riddlesden	Overall	Braithwaite	Riddlesden	Overall	Braithwaite	Riddlesden	Overall	Braithwaite	Riddlesden	Overall
Location (Braithwaite, Riddlesden, Other)	/	/	- (n=120)	/	/	0.010 (n=75)	/	/	- (n=111)	/	/	- (n=172)
Gender (male, female)	- (n=40)	- (n=46)	- (n=166)	- (n=19)	- (n=31)	- (n=106)	- (n=37)	- (n=34)	0.046 (n=152)	- (n=82)	0.039 (n=33)	- (n=210)
Age (16-24, 25-59, 60+)	- (n=44)	- (n=45)	0.004 (n=181)	- (n=21)	†††	- (n=115)	- (n=43)	- (n=41)	- (n=169)	- (n=90)	- (n=39)	- (n=228)
BME (BME, non-BME)	- (n=44) BME=1	- (n=45) BME=2	- (n=180) BME=4	- (n=21) BME=1	†††	- (n=113) BME=2	- (n=43) BME=2	- (n=41) BME=3	- (n=169) BME=5	- (n=90) BME=3	- (n=38) BME=2	- (n=227) BME=7
Restricted mobility (yes / no)	0.025 (n=44)	- (n=46)	0.000 (n=181)	- (n=21)	- (n=31)	- (n=115)	- (n=43)	- (n=41)	- (n=169)	0.006 (n=90)	- (n=39)	- (n=228)
Looking for work (yes / no)	- (n=43) Unemp=1	†††	- (n=179) Unemp=9	†††	†††	- (n=114) Unemp=5	†††	- (n=41) Unemp=1	- (n=166) Unemp=7	- (n=89) Unemp=6	- (n=39) Unemp=1	- (n=225) Unemp=17
Travelling with children (yes / no)	- (n=44) Yes=6	- (n=45) Yes=4	- (n=180) Yes=24	- (n=21) Yes=1	- (n=30) Yes=1	- (n=113) Yes=10	- (n=43) Yes=7	- (n=40) Yes=1	- (n=167) Yes=25	- (n=90) Yes=15	- (n=39) Yes=1	- (n=228) Yes=35

† Test used: Kruskal-Wallis (shows if both populations have the same median), even if there were only two categories within the social groups, as it gave the same results as Mann-Whitney U.

†† One empty group – test could not be performed.

††† Small too sample sizes or one empty group

Table 2 shows whether there is a significant difference in the median values according to various social and modal groupings. As can be seen, due to the small sample sizes, tests could only be performed for the choice between walking up a steep hill or accepting a longer walk on the flat. Here the median value varies significantly according to the health condition of the respondent and the age group – so using average, population-wide values is inappropriate.

Table 2: Significant relationships between median values and population sub-groups among residents in Keighley[†]

	Avoid walking up a steep hill	Prefer a bus stop with seating/shelter	Avoid crossing busy road	Prefer well lit route
Location (Braithwaite, Riddlesden, Other)	-			
Gender (male, female)	-	-	††	††
Age (16-24, 25-59, 60+)	0.041	††	††	††
BME (BME, non-BME)	-	††	††	††
Restricted mobility (yes / no)	0.001	††	††	††
Looking for work (yes / no)	-	††	††	††

[†]Median test X²

^{††} Test could not be performed

TOWER HAMLETS

Avoid crossing busy road: Table 3 highlights a significant difference in the ‘point of change’ between males and females (p=0.002), age groups (p=0.000) and (un)restricted mobility (p=0.004), when there is a choice of crossing a busy road without an official crossing or walking further to an official crossing. When the responses were examined by mode, for the DLR users there were significant differences between genders (p=0.002) and the age groupings (p=0.011). For those that travel by bus, difference in ‘point of change’ only occurred between the age groups (p=0.001). Whereas for those travelling by tube, the only significant difference was between those that have restricted mobility and those with unrestricted mobility (p=0.002).

Avoid poorly lit route: There were only two instances where significant differences occurred in the ‘point of change’ for the trade-off between walking further along a well lit road and walking a shorter distance along a poorly lit road. These were: BME verses non-BME when all modes were combined (p=0.027), and between male and female who were travelling by tube (p=0.000).

Further analysis was then carried using the Median test, to assess the appropriateness of using the overall median of the group to represent each of its subgroups. This test could only be performed when the modes of transport were combined, as the sample size was too small for separate analysis by mode.

Table 4 shows the results of the Median test, which broadly confirmed the outcomes of the previous tests (Table 3) and verified that the overall median walk time would not give a good approximation of the appropriate values within the following groups:

Avoid crossing busy road

- Mode of transport: the median walk time over estimated the time penalties for underground and DLR and slightly under estimated them for bus. (p=0.012);

- Gender: the median walk time penalty over estimated the values for males and underestimated them for females (p=0.005);
- BME: the median walk time penalties under estimated the values for the BME group and over estimated them for the non-BME group (p=0.000) and;
- Restricted/Unrestricted mobility: the median walk time penalty under estimated the values for those with restricted mobility and over estimated those with no mobility restrictions (p=0.004).

Avoid poorly lit route

- Mode of transport: the overall median walk time ratio provided a good approximation for the sub-group 'tube', slightly under estimated the value for DLR users, and over estimated the value for bus – where all respondents fell below the overall median. (p=0.000) and;
- BME: the overall median walk time penalty slightly under estimated the values for the BME group and slightly over estimated for the non-BME group (p=0.027).

Table 3: Significant difference in 'point of change' between groups (p-value)

	Avoid crossing busy road				Prefer well lit route			
	Tube	DLR	Bus	All Modes	Tube	DLR	Bus	All Modes
Gender (male, female)	-	0.002 [†]	-	0.002 [†]	0.000 [†]	-	-	-
Age (16-24, 25-59, 60+)	-	0.011 ^{††}	0.001 ^{††}	0.000 ^{††}	-	-	-	-
BME (BME, non-BME)	-	-	-	-	-	-	-	0.027 [†]
Restricted mobility (yes / no)	0.002 [†]	-	-	0.004 [†]	-	-	-	-
Travelling with children (yes / no)	-	-	-	-	-	-	-	-

[†] Test used: Mann-Whitney

^{††} Test used: Kruskal-Wallis

Table 4: Significant relationship between median and grouping relationship (all modes combined)

	Avoid crossing busy road	Prefer well lit route
Mode of transport (Bus, Underground, DLR)	0.012 [†]	0.000 [†]
Gender (male, female)	0.005 [†]	-
Age (16-24, 25-59, 60+)	0.000 [†]	-
BME (BME, non-BME)	-	0.027 [†]
Restricted mobility (yes, no)	0.004 [†]	-
Travelling with children (yes, no)	-	-
Looking for work (yes, no)	-	-

[†]Median test χ^2