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Comparing Objective and Subjective Measures of Journey Time Accessibility

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Abstract

This paper presents work undertaken as part of PhD research towards understanding how existing objective measures of accessibility relate to individual perceptions or the “lived experience” of accessibility. Since 2003, accessibility has been framed in the social exclusion context within UK transport planning and policy, focusing on the ability of people to participate fully in society, which is seen as being limited by poor accessibility. Accessibility planning recognises that factors other than spatial location are important and places importance on barriers to accessibility such as information, cost, comfort, physical access and, safety and security as well as provision of transport services and journey times (Social Exclusion Unit, 2003). Despite this recognition, accessibility measures and indicators tend to focus on the more easily measurable journey time or distance of people to destinations, and do not consider more subjective factors such as convenience, physical mobility, safety and cost which are important to individuals in how they perceive their accessibility, and which will ultimately impact travel behaviour. If Accessibility Planning is to have the desired impacts on people’s lives then it is important that we understand what matters to individuals in perceiving their own accessibility, and that measures used in policy relate to this.

The aim of this paper is to present to results of some exploratory data analysis undertaken to understand differences between objective and subjective measures of journey time accessibility to a range of services, using two secondary datasets available in England. These are the National Travel Survey and Core Accessibility Indicators.

Introduction

The overall subject of this research is to understand the “lived experience” of accessibility, and how this “lived experience” or individual perceptions of accessibility relate to existing objective measures of accessibility.

While it might be claimed that everything is subjective to some extent and therefore questionable whether true objectivity is possible (Muckler, 1992), the terms are widely used in social indicators research (eg Diener, 1997; Wish, 1986; Parks, 1984; Kuz,1978), with subjective relating to citizens experiences, perceptions and evaluations of their own ‘reality’, and objective being the ‘official reality’ as measured by government agencies. For example, van Acker et al (2010) give the example of low motorised traffic levels meaning a neighbourhood is objectively evaluated as pedestrian friendly but that certain individuals may not perceive it to be so. In this paper therefore, objective relates to a government indicator or measure designed to reflect the ‘real’ situation, and subjective is used to understand an individual perception or experience of that reality, as explained by Pacione (1982) objective indicators are “*hard measures, describing the indicators within which people live and work*” whereas subjective indicators “*describe the way people perceive and evaluate conditions around them*”. While recognising that accessibility is affected by a much wider range of factors, this paper presents a comparison of objective and subjective measures of *journey time* accessibility, based on analysis of two secondary datasets. The National Travel Survey (NTS) represents a subjective understanding of journey times based on survey responses, whilst the Core Accessibility Indicators (CAI) are designed as an objective measure of journey time accessibility using a model approach.

There is no universal agreement regarding the definition of accessibility as applied in transport studies and the concept has been understood and applied differently by people at different times and in different places. To take the dictionary definition, accessibility is “*The quality of being accessible, or of admitting approach*”; and accessible is defined as 1) “*capable of being used as an access; affording entrance; open, practicable*” or 2) “*capable of being entered or reached; ease of access; such as one can go to, come into the presence of, reach, or lay hold of; get-at-able.*” (Oxford English Dictionary)

In this sense then, accessibility can be interpreted as the extent to which something is accessible. In the context of transport planning it has generally been understood more specifically as the ability of people to access places, with transport as the main means by

which this accessibility is provided, even for very short journeys where walking is the mode of transport, though virtual mobility (eg online banking/mobile working) means that transport is no longer always a necessary requirement for accessibility needs to be met. Geurs and van Eck (2001) define accessibility as *“the extent to which the land-use transport system enables (groups of) individuals or goods to reach activities or destinations by means of a (combination of) transport mode(s)”*. The Social Exclusion Unit (SEU) defines accessibility as the *“ease with which people can access goods and services”* and asking *“can people get to key services at reasonable cost, in reasonable time and with reasonable ease?”* (SEU,2003) Defining accessibility in this way makes it more difficult to measure as ‘ease’ and ‘reasonable’ will be interpreted differently depending upon the individual context. Within this definition the SEU emphasises the need for consideration of physical availability of transport, journey time, cost, information, safety and security and travel horizons.

Such differing understandings will lead to the concept being applied in different ways depending on the definition adopted. In order to develop a practical application of accessibility there is a need to develop appropriate and meaningful measures of accessibility that can be utilised in planning and policy decisions and measure variation both temporally and spatially. Typically measures will be person based (the ability of people to access destinations) or place based the accessibility of a place to the population)

The process of Accessibility Planning represents one example of formalising an approach to measuring and applying the concept of accessibility within transport planning. Accessibility Planning is the process by which accessibility problems are tackled throughout the whole transport chain, in order to improve social inclusion, which, in the UK falls within the remit of transport (DfT, 2004). A report by the FIA Foundation¹ (FIA Foundation, 2007) suggests that the UK is unique and ahead of other nations in considering access to a *range* of services, such as healthcare, education and healthy food in the context of social exclusion. In the six other nations examined by the FIA, only access to employment was usually considered in the context of promoting inclusion, with France and the USA being seen as most advanced in this area, for example through the Transport Equity Act (USA) and welfare to work schemes.

Considerable progress has been made in mainstreaming accessibility into transport planning in the UK through the local transport planning process and the development of national core

¹ Fédération Internationale de l'Automobile (<http://www.fiafoundation.org/Pages/homepage.aspx>)

indicators for accessibility against which local authorities can benchmark themselves.² Accessibility Planning in the UK is framed in the context of social exclusion within transport planning and policy, focusing on the ability of people to participate fully in society, which is seen as being limited by poor accessibility (DfT, 2004). The approach follows a five stage process; 1) Strategic (e.g. LTP wide) accessibility assessment; 2) Local accessibility assessments, focussed on priority areas, groups & issues; 3) Option appraisal (including the identification of resources); 4) Accessibility action plan development and delivery; and 5) Monitoring (DfT,2004).

Measurement of accessibility and development of indicators such as the Core Accessibility Indicators used in the paper support this process alongside tools such as user and stakeholder consultation. This approach recognises that factors other than spatial location are important and places importance on barriers to accessibility such as information, cost and, safety and security as well as provision of transport services and journey times (Social Exclusion Unit, 2003). Despite this recognition, accessibility measures and indicators tend to focus on the objective journey time or distance of people to destinations, given the availability of such data, and do not usually consider factors that are more difficult to measure such as convenience, physical mobility, safety and cost, or subjective understandings of these factors. It must be noted that factors other than time are considered in the overall *process* of Accessibility Planning for example through use of local consultation to understand the issues, and the need for different approaches to accessibility is recognised for example in Scottish Transport Appraisal Guidance (STAG)³ which measures stated, expressed, social and comparative accessibility.

Recognition of this schism between objective measures and subjective understandings is clearly not a new issue - Morris et al. (1979) wrote that “*perceived accessibility and perceived mobility – the real determinants of behaviour – will be at variance with “objective” indicators of accessibility and mobility.*” Despite this there is still little practical understanding of how and why they vary in transportation research. However, evidence from other fields suggests there is a difference between the two (eg Parks, 1984). A greater understanding of this difference, and reasons for it, would enable policy interventions to be appropriately targeted and more desirable outcomes to be achieved, by ensuring that improvements in both perceived and actual accessibility are achieved where necessary. While

² For a review of the progress made with Accessibility Planning see Halden (2009)

³ http://www.transportscotland.gov.uk/stag/td/Part2/Accessibility_and_Social_Inclusion

recognising the importance of subjective measures, it is also necessary to remember the value of objective measurements, and their importance in policy development. Stanley & Vella-Brodrick (2009), warn that; *“while the subjective perspective is important, such measures do not account for value-based social policy social justice principles.....an individual may be personally satisfied with their circumstances if they have diminished capabilities, social justice dictates that they should be offered the choice to be able to participate fully in society. This position subsumes the value judgement that it is not sufficient to allow people to simply adjust or accommodate to adverse circumstances”* (Stanley & Vella-Brodrick 2009). So, while an understanding of subjective views of accessibility is important in determining travel behaviour, equally objective measures are important to measure progress and change against. This suggests that simply using subjective measurements would not be an appropriate policy response due to the tendency of people to adjust to adverse circumstances, and perhaps under-assess their need, or to raise their expectations following improvements. In addition objective measurements, against which progress can be monitored are a requirement of UK government policy. A method incorporating both objective and subjective measures would therefore be best placed to deepen our understanding of accessibility and enable interventions to be appropriately targeted.

From review of international experience to date it seems that while there is a considerable body of work attempting to develop objective measures of accessibility and also a separate body of work that seeks to understand people’s perceptions and experiences of travel, there is limited work that directly compares the two approaches to understanding accessibility, for a given area or population group. In a recent review van Acker et al (2010) explain that while most empirical studies *“use objective variables that refer to characteristics of each level or environment.....these objective variables are, however, perceived and evaluated by individuals with specific lifestyles. Nevertheless, almost none of these studies questions whether perceptions correspond to the objective reality”* (Van Acker et al, 2010) Exceptions include Lotfi & Koohsari (2009), van Exel & Rietveld (2009) and Tilt et al (2007). Lotfi & Koohsari (2009) use three objective measures (Infrastructure, Activity and Utility based) and compare these with a subjective approach based on interview and questionnaire data. What they find is that those areas with the highest “measures” of accessibility are not perceived as such by residents (in terms of satisfaction with access to facilities) due to issues of safety and security. van Exel & Rietveld (2009) investigate transport choice sets for commuters, and found that the ratio of perceived to objective travel times strongly influenced modal choice. Car users

over-estimated objective measures of public transport times by 46%. This shows that if more can be done to understand the difference between perceived and actual accessibility, then improvements in perceived accessibility, and therefore travel behaviour may be possible. Tilt et al (2007) used objective and subjective measures of accessibility and vegetation in a residential area to explore the relationship between these and walking activity and Body Mass Index (BMI). They found relationships between objective and subjective accessibility ($r=0.329$) and found that walking trips per month were related to objective measures of accessibility, but to subjective measures of greenness. This highlights the importance of understanding both objective and subjective views of factors influencing accessibility, and how these interact to influence behaviour.

The aim of this research therefore is to understand what factors are important to individuals in their perceived or “lived” accessibility and how these are at variance with objective measures of accessibility employed by policy makers. It is expected that perceived levels of accessibility will vary from objective measures for two principal reasons. Firstly, objective measures may not measure what is important in determining individuals perceptions of their own accessibility or the calculation methods may mean these are not accurate, and secondly individuals’ perceived accessibility may be affected by external factors, for example lack of information. For example, considering accessibility to GP surgeries, a measure may be inaccurate due to an incorrect GP dataset or a measure of time may be inappropriate if comfort is more important for an individual accessing their GP surgery, likewise perceptions may be inaccurate if an individual is not aware of a GP surgery that is more accessible than the one they currently attend, or they are not aware of a community transport service which could provide them with access to the surgery.

Two existing datasets provide an interesting starting point for this work and are the subject of this paper. The UK National Travel Survey (NTS) contains questions pertaining to how long it takes (subjectively) for respondents to reach given destinations and the Core Accessibility Indicators (CAI) use an accessibility model to derive a wide range of (objective) accessibility indicators for England⁴. A more detailed introduction to the two datasets is provided in the following section.

Using the time based indicators from the CAI dataset and the relevant responses from the NTS a comparison of the objective and subjective measures of *journey time* accessibility to

⁴ England is one of the constituent nations of the UK, and different indicators are calculated for Scotland and Wales which are not considered in this paper

key services can therefore be undertaken, which goes some way to addressing two of the overall objectives of this PhD, namely:

- To critically assess the current approach to accessibility planning, and the tools available for this – and in doing so to *identify gaps between current objective measures and perceptions of accessibility in order to gain insight into how current modelled accessibility relates to ‘lived experience’* and therefore how measures can be improved.
- To develop, through use of appropriate case studies, a deeper *understanding of the relationship between objective and subjective accessibility* and therefore to understand for whom accessibility is important, and what is important, therefore identifying who will benefit from transport and non-transport improvements.

The two datasets have therefore been matched in order to undertake an analysis of the difference between objective and subjective measures of time based accessibility based on available existing datasets. This provides a useful starting point for understanding how different approaches to measuring accessibility may vary and to identify where further research is needed and what data will it will be important to obtain through primary data collection.

Description of Datasets

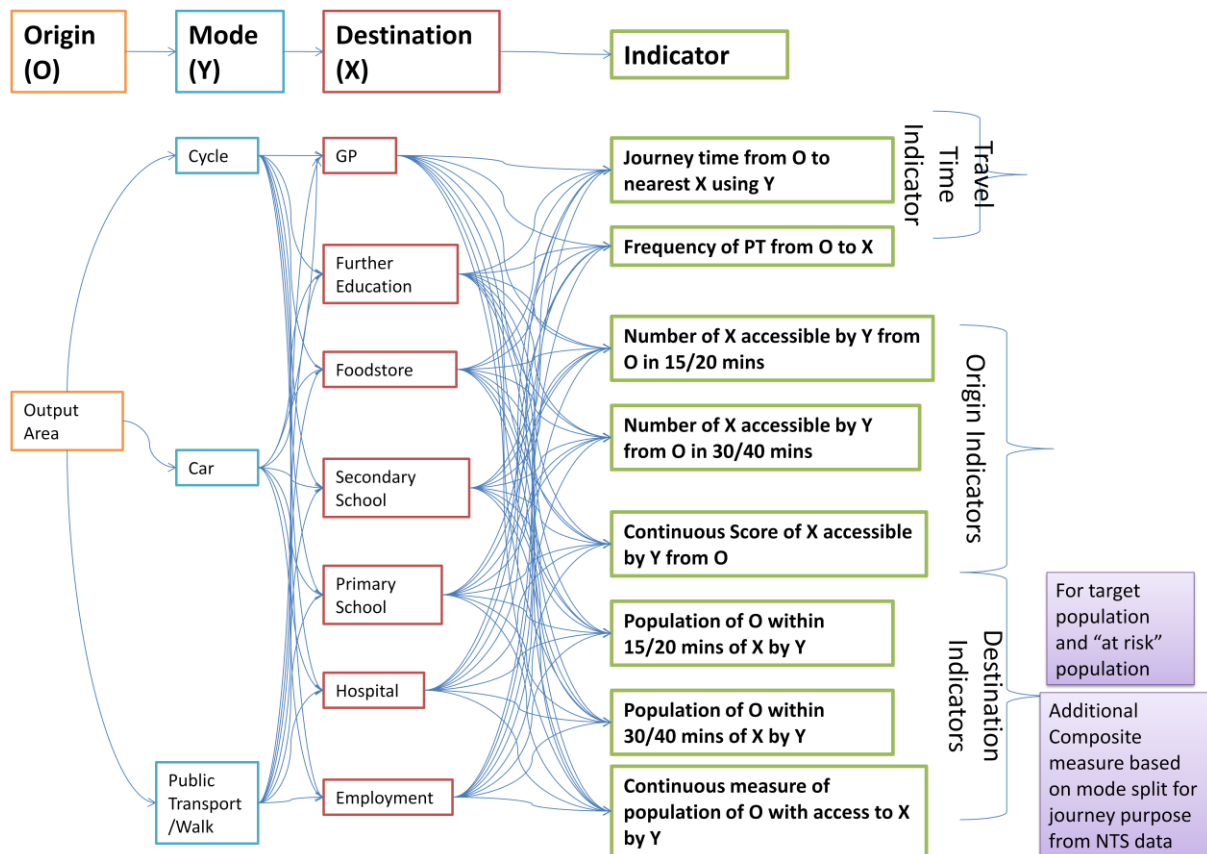
The **Core Accessibility Indicators** (DfT, 2009) are calculated to support Local Authorities in England in developing an evidence base for Accessibility Strategies as part of the Local Transport Planning process and to support two of the 198 National Indicators (NI)⁵ against which Local Authorities may choose to report as part of their reporting the central government. This is the means by which central government manages the performance of local government and is linked to funding. A range of accessibility indicators are produced, these can be split into 1) Origin Indicators; 2) Destination Indicators and 3) Time based indicators. These are calculated at Census Output Area (COA)⁶ and reported at Super Output

⁵ NI175 - Access to Services and NI 176 - Access to Employment

⁶ Census Output Areas (COA) are the smallest level at which UK census data is output. They were designed to have similar population sizes and be as socially homogenous as possible. In England and Wales 2001 Census OAs are based on postcodes as at Census Day and fit within the boundaries of 2003 statistical ward. The minimum OA size is 40 resident households and 100 resident persons but the recommended size was rather larger at 125 households. (http://www.statistics.gov.uk/geography/census_geog.asp)

Area (SOA)⁷ and Local Authority (LA)⁸ levels for seven service types (GP, Hospital, Foodstore, Primary School, Secondary School and Further Education) and three modes (Public Transport/Walk, Car and Cycle). To illustrate this, Figure 1 shows the indicators available in the Core Accessibility Indicator dataset. Following the diagram it can be seen that each indicator is produced for seven service (destination) types and three modes.

Figure 1 - Core Accessibility Indicators



Indicators have been calculated for 2005, 2007 and 2008 and will shortly be published for 2009, using a GIS based accessibility model for the UK, originally developed for the Scottish Government in 1999 (Halden et al, 2000) and further refined for DfT in 2003(Halden & University of Westminster, 2003). Given a change in approach the structure outlined in Figure 1 is only applicable for 2007 onwards. Further details on the calculation methods and datasets

⁷ Super Output Areas (SOA) are a level of geography designed for collection and publication of small area statistics and contain an average of 1500 people (min: 1000 people=400 households)⁷ and will therefore vary in size depending upon population density. SOAs are based on aggregation of COAs.

⁸ A Local Authority is a unitary authority or district council, with responsibilities such as housing, council tax, waste collection. In areas where there is a two tier system of governance, responsibility for transport usually lies with the higher level County Council. As at April 2009 there were 272 Local Authorities in England (<http://www.communities.gov.uk/housing/housingresearch/housingstatistics/definitiongeneral/>)

used in the calculations are available on the Department for Transport (DfT) website.⁹ It is beyond the scope of this paper to look at the data accuracy issues within the CAI dataset, for example whether the destination dataset used for hospitals is a reflection of the hospitals available to any individual, given healthcare sector policies, or indeed whether an individual perceives a GP in the destination set to be in their destination choice set. However, it is likely that some of these issues will explain the reasons for differences between subjective and objective measures of time, and based on this will set the context for further work.

The **National Travel Survey** (DfT, 2010) is a UK-wide continuous household survey (since 1988) on personal travel. A wide range of information is collected by the survey and more information is available from the DfT website.¹⁰ Of interest here is a series of questions pertaining to travel times to key services. The questions asked are: *“How long would it take to get to the nearest (GP/Hospital/Chemist/Post Office/Secondary School/Primary School/College/Grocer/Shopping Centre) on foot or by public transport using whichever is the quickest?”* Respondents are given a show-card with the following options: 1) 15 mins or less; 2) 16-20 mins; 3) 21-30 mins; 4) 31-40 mins; 5) 41-60 mins; 6) 61 mins or longer, and as such, the dataset is categorical. These questions are asked in order to monitor access to services across different types of area (eg rural/urban) (DfT, 2010b). Data is currently available up until 2006.¹¹

It can be seen therefore that both of these datasets contain similar information relating to the accessibility of key services, and both are designed to monitor the level of accessibility of the population to these services. However, the data collection methods mean that the Core Accessibility Indicator (CAI) data is regarded as an objective measure, based upon the location of services and the transport networks, whilst the National Travel Survey (NTS) data is regarded as a subjective measure relating to respondents' perception of their journey time to key services, which will be based upon their perception of the location of services and transport networks. As explained in the introduction both objective and subjective understandings of accessibility are important in planning transport and land use. Time is just

⁹ DfT(2009a);DfT(2009b) available from <http://www.dft.gov.uk/pgr/statistics/datatablespublications/ltp/coreaccessindicators2008> (Accessed: 27/05/2010)

¹⁰ DfT (2010a)<http://www.dft.gov.uk/pgr/statistics/datatablespublications/personal/mainresults/nts2008> (Accessed: 27/05/2010)

¹¹ Because of this, this paper uses 2006 NTS data with 2007 CAI data, as previous years CAI do not contain the same level of detail or robust approach. However, in July 2010 NTS data for 2007 and 2008 will be released and therefore direct comparisons can be made with 2007 and 2008 CAI data prior to the conference date in August.

one factor that affects accessibility, and it is this time based accessibility that is studied in this paper.

There are six destinations common to both of the datasets: **GP, Hospital, Foodstore, Primary School, Secondary School and Further Education (FE)/College**. These destinations are therefore used in this analysis.

Methodology

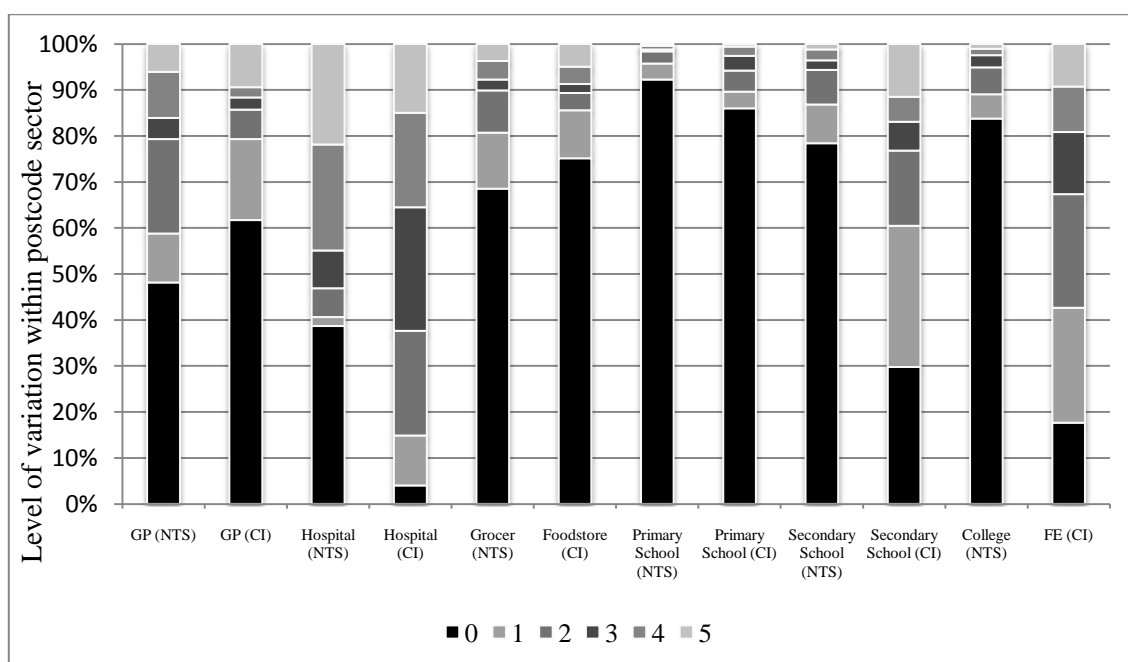
The level of geography of the two datasets varies so the initial step was the match the two together. The Core Accessibility Indicators (CAI) are reported at Super Output Area (SOA) and the lowest level of geography available from the National Travel Survey (NTS) is the postcode sector which was provided as a custom dataset by the Department for Transport (DfT). SOA are a level of geography designed for collection and publication of small area statistics and contain an average of 1500 people (min: 1000 people=400 households)¹² and will therefore vary in size depending upon population density. Postcode sectors are the second level of UK postcode geography and there are 11598 in the UK, containing on average 153 unit postcodes¹³, and will again vary with population density. The two units of geography do not fit neatly together, so while postcode sectors are larger than SOA the boundaries overlap. Each postcode sectors contains an average of 14 (min:1; max:41) SOA and each SOA falls into an average of 3 (max:26; min:1) postcode sectors which gives some idea of the overlap between the two. This is problematic when combining the two datasets as the data cannot simply be aggregated, which in itself would create errors. There are widely reported problems of comparing aggregated data at different spatial scales and this may result in errors or loss of data. This is know as the modifiable areal unit problem (Openshaw & Taylor, 1981) and is based on the understanding that analysing spatially aggregated data gives results that are somewhat dependant on the units to which the data are aggregated (Fotheringham et al, 2001). In this case therefore the CAI are aggregated time values, calculated at COA and reported at SOA, and by aggregating to postcode sector this is open to further problems of aggregation, it is therefore crucial to consider how the data is aggregated for comparison with NTS data at the postcode sector level.

¹²<http://www.neighbourhood.statistics.gov.uk/dissemination/Info.do?page=aboutneighbourhood/geography/superoutputareas/soafaq/soa-faq.htm> (Accessed: 27/05/2010)

¹³http://www.statistics.gov.uk/geography/postal_geog.asp (Accessed: 27/05/2010)

Initially the two datasets were matched by assigning a journey time from the Core Accessibility Indicator (CAI) dataset to each case in the National Travel Survey (NTS) dataset by taking the centroid of the postcode sector for each NTS case and using the CAI value of the SOA within which the postcode sector centroid falls. In this instance using the postcode centroid means that the CAI value assigned to the NTS data may not be representative of the entire postcode sector. Therefore an alternative approach was also taken whereby the CAI values were aggregated to postcode sector level by calculating a weighted value of journey time based upon the proportion of each postcode sector covered by each SOA. The results from each approach are presented in the following section, and while not affecting the results significantly in the majority of cases, the proportional based approach is believed to be a more robust approach, given that it represents the range of CAI results within any given postcode sector. An additional check was made by looking at the distribution of values (both NTS and CAI) found in each postcode sector. The sampling procedure used for NTS means that 22 households are sampled per postcode sector, and as has already been identified there are an average of 14 SOAs within a postcode sector, meaning that there is potentially a great deal of variation, both of NTS responses and the CAI values, within a postcode sector. The difference between the maximum and minimum values (NTS and CAI) within each postcode sector was therefore calculated for each destination type. Figure 2 shows that in most cases over 50% of the postcode sectors have no variation within them.

Figure 2 - Proportion of Postcode Sectors where the difference between maximum and minimum category value is (0,1,2,3,4,5)



However, for hospitals, secondary schools and Further Education there is a large proportion of postcode sectors with variation within them for the CAI values, and hospitals and GPs show variation for the NTS responses. Given that the analysis in this paper uses each NTS response then this variation is already considered, however, the use of a single CAI value to represent a postcode sector means this variation is not accounted for and needs to be considered when drawing conclusions from the results. This does however add weight to the reasoning for using the proportional based measure as this is more representative of all the CAI values within a postcode sector.

The combined dataset contains the original NTS responses with additional ‘objective’ journey time measurements attached for each of the six destination types listed above. Given the categorical nature of the NTS data as outlined in the introductory section the CAI variables were re-coded into comparable categories. There are 7428 cases in the NTS 2006 dataset and 6883 of these were successfully geocoded. Table 1 shows the number of valid cases in both the NTS dataset and the matched CAI dataset and the number of valid cases successfully matched. The reason for the low number of valid cases for Primary School, Secondary School and Further Education is that respondents were only requested to answer this question if it was deemed appropriate (ie children aged 5-11 living in the household for primary schools).

Table 1 – Frequencies of variables used from NTS, CAI and matched datasets, for each destination type

		GP	Hospital	Food store	Primary school	secondary school	Further education/ college
NTS	Valid	6865	6882	6896	920	849	654
	Missing	563	546	532	6508	6579	6774
	Total	7428	7428	7428	7428	7428	7428
CAI	Valid	6883	6882	6883	6883	6883	6883
	Missing	545	546	545	545	545	545
	Total	7428	7428	7428	7428	7428	7428
Matched	Valid	6848	6864	6879	917	849	650
	Missing	545	580	549	6511	6579	6778
	Total	7428	7428	7428	7428	7428	7428

In order to test whether there is a difference between the objective and subjective measures of time based accessibility the following hypotheses were formulated.

For a given postcode sector there is a difference between subjective (NTS journey time) and objective (CAI journey time) measures of journey time accessibility

The difference between objective and subjective measures of journey time accessibility will vary dependent upon: a) journey time and b) rurality

Analyses are undertaken to understand whether the differences between the measures occurred uniformly across spatial and temporal continuum. Based on initial analyses it was noticed that the difference between the objective and subjective measures appeared to be larger for destinations that may typically be further away from the origin point, therefore the difference objective and subjective measures was is the continuous journey time from the CAI dataset.

Analysis is then undertaken by splitting the dataset using a classification of urban/rural areas¹⁴. Differences are expected to occur given the differing nature of mobility and accessibility in urban and rural areas, meaning variations in perceptions would be expected. Additionally the variation in the size of super output areas in urban and rural areas (see above) means that errors may occur within the CAI dataset and so differences in accuracy between urban and rural areas are expected here as well.

Finally, given that variation occurs within the urban-rural categories, it is expected that journey time is still significant in accounting for differences, once scale is controlled for, and given that the CAI are known to have problems for short journey times (<10 minutes) further analysis is undertaken by splitting the dataset according to the journey time category.

Analysis and Results

Paired *t*-tests¹⁵ were used to test the difference between objective and subjective measures of journey time accessibility for a given postcode sector and the results are shown

Table 2 and Table 3 for both approaches to aggregating the data described in the methodology section.

¹⁴ <http://www.defra.gov.uk/evidence/statistics/rural/rural-definition.htm> (Accessed 30/05/2010)

¹⁵ A non-parametric Wilcoxon test was also undertaken and the results did not significantly differ, therefore the *t*-test results are used in this analysis as it is a stronger statistical test and the difference between the two datasets satisfies conditions of normality (Field, 2009)

The *t*-test results show there is a significant difference ($p < 0.05$) between the datasets for all destination types, using both methods of assigning a CAI value to the NTS data, except for primary schools and secondary schools, when using the postcode centroid to assign the value and secondary schools when using the weighted CAI value.

Table 2 – Dependant *t*-test results for difference between in journey time category between subjective (NTS) and objective (CAI) measures of journey time accessibility (using postcode centroid based CAI value)

	N	Mean	St. dev	confidence intervals		<i>t</i>	df	<i>p</i>
				lower	upper			
GP	6865	0.101	1.416	0.068	0.013	5.915	6864	0.000
FE	654	0.161	1.807	0.022	0.299	2.272	653	0.023
Hospital	6882	0.840	2.227	0.787	0.893	31.294	6881	0.000
Foodstore	6896	-0.045	1.086	-0.070	-0.019	-3.416	6895	0.001
Primary School	920	0.038	0.912	-0.021	0.097	1.264	919	0.206
Secondary School	849	0.777	1.666	-0.034	0.190	1.360	848	0.174

Table 3- Dependant *t*-test results for difference between in journey time category between subjective (NTS) and objective (CAI) measures of journey time accessibility (using proportion based CAI value)

	N	Mean difference	St. dev	confidence intervals		<i>t</i>	df	<i>p</i>
				lower	upper			
GP	6848	0.905	1.420	0.057	0.124	5.275	6847	0.000
FE	650	0.220	1.842	0.078	0.362	3.045	649	0.002
Hospital	6864	0.790	2.212	0.738	0.843	26.602	6863	0.000
Foodstore	6879	-0.400	1.016	-0.064	-0.016	-3.264	6878	0.001
Primary School	917	0.082	0.791	0.031	0.133	3.132	916	0.002
Secondary School	849	0.107	1.606	-0.001	2.157	1.945	848	0.052

Given only small variation in overall conclusions at this level (ie primary school change from not significant to significant difference is the only change), from this point forward the weighted CAI value will be used in analyses as this is believed to be more theoretically robust as it accounts for all CAI values occurring within a postcode sector, but the impacts this has on the results and conclusions, particularly for primary schools must be considered. Based on this, and therefore taking forward the results from Table 3 the alternative hypothesis can be accepted for all destination types, except for secondary schools, and therefore *there is*

significant difference between the two datasets. However, when breaking down the results different patterns emerge.

Comparing the difference between the two values with the continuous journey time from the CAI dataset

This was undertaken in order to ascertain whether there was any relationship between the length of trip and whether or not there was a significant difference between the datasets. For trips to destinations further away from the origin point that there might be a larger difference, as it may be harder to estimate journey times for further and perhaps more infrequent trips (eg hospital as opposed to GP). In order to test whether there was any relationship between the scale of the difference between the datasets and the length of the journey, for each destination type Spearman's rank correlation was undertaken of the difference between categories (NTS-CAI), with the actual journey time value from the core indicators (as a measure of length of trip from origin point) and the results are shown in Table 4.

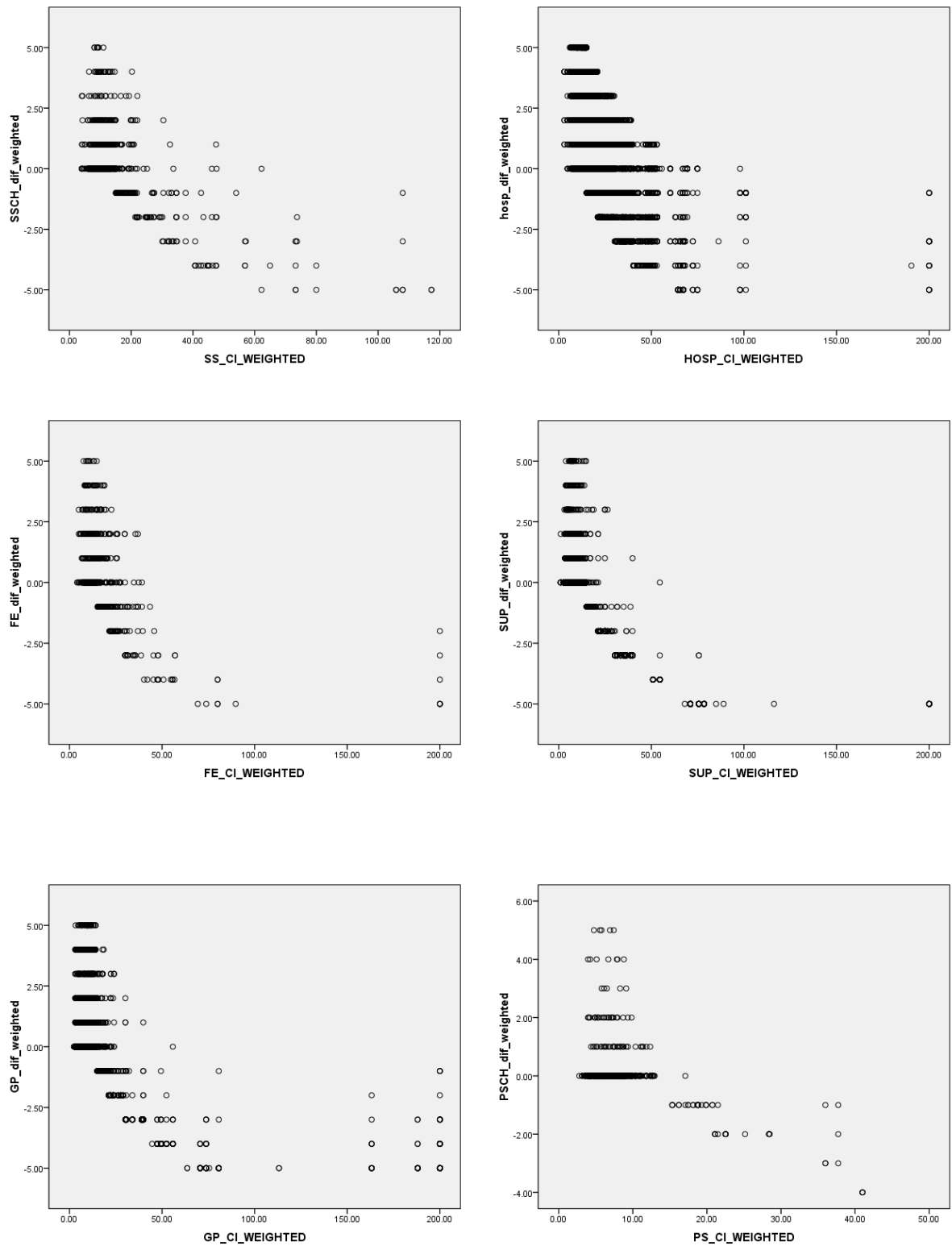
Table 4 - Spearman's Rank Correlation co-efficients for the difference between subjective and objective journey time (NTS-CAI) against objective journey time (CAI)

Destination	Correlation co-efficient	<i>p</i>
GP	-0.374	0.000
FE	-0.547	0.000
Foodstore	-0.351	0.000
Hospital	-0.592	0.000
Secondary School	-0.519	0.000
Primary School	-0.235	0.000

It can be seen that there is significant, but not particularly strong, correlation between the difference between the two datasets and the journey time. However, given that the difference ranges from -5 to +5 it is in fact the direction of the difference that is being tested here and not the magnitude as illustrated by the graphs in Figure 3.

These graphs show that negative differences (NTS<CAI) occur for journey times whereas positive differences (NTS>CAI) tend to have shorter journey times. To test whether there is significance in the direction of the difference, new variables were created to create two groups (NTS<CAI) and (NTS>CAI).

Figure 3 – Scatter Plots showing (NTS-CAI) against CAI journey time.



Error! Not a valid bookmark self-reference. shows the mean values of the continuous CAI journey time for the two groups and the results of a *t*-test of difference between these.

Table 5- Results of *t*-test for comparing the mean objective journey time between (CAI>NTS) and (CAI<NTS)

	mean when: CAI>NTS	mean when: CAI<NTS	<i>t</i>	<i>p</i>
FE	34.709	13.369	7.917	0.000
Foodstore	35.541	7.984	19.903	0.000
Secondary School	32.283	11.518	12.389	0.000
Primary School	24.155	7.005	14.497	0.000
GP	58.483	9.238	21.454	0.000
Hospital	35.279	17.679	32.884	0.000

It can be seen that there is a significant difference ($p < 0.05$) between the means where (CAI>NTS) and (CAI<NTS). Therefore for shorter journeys based on the objective measure the subjective (NTS) responses are generally longer than would be expected from the Core Accessibility Indicators, and for longer journeys the NTS responses are lower than would be expected from the Core Accessibility Indicators. As discussed in the methodology section the Core Accessibility Indicators are calculated at Census Output Area (COA) level, the size of which varies with density of population. This can lead to errors in the dataset, which might be what is being illuminated by this analysis. For example, Super Output Areas (SOA) may have shorter than expected CAI journey times due to journey times being calculated from the population weighted centroid of a COA which is also likely to be where services are located, but journey time in the periphery may be much longer. Given the varying size of SOA the differences are likely to be different in rural and urban areas, due to the nature of the way the data is assembled.

Splitting the analysis by using a further secondary dataset – classification of urban/rural areas

In order to assess the relationship of these results to the location, analysis has been undertaken looking at the results in relation to the urban/rural classification used by the Department for the Environment Food and Rural Affairs (DEFRA) and looking at each journey time category separately.

The rural-urban definition is a categorisation used by DEFRA and defines SOAs into one of the following three categories:

- Urban (>10k population)
- Town and Fringe
- Village, Hamlet and Isolated Dwellings

There is a further morphological categorisation of each of these into sparse and less sparse, but using these sub-categories resulted in groups too small for this analysis. The dataset was split into these three categories in order to ascertain the impact of geographical location (and therefore scale of measurement) on the results. In other words this was undertaken to control for the geographical setting, as larger rural SOA or postcode sector could have different errors within the CAI dataset, to smaller urban SOA.

Table 6 – Dependant *t*-test results for difference between in journey time category between subjective (NTS) and objective (CAI) measures of journey time accessibility, split by urban-rural classification

		N	Mean of differ ence	St. dev	confidence intervals lower upper		<i>t</i>	<i>p</i>
GP	Urban >10k	5154	0.355	1.061	0.326	0.384	24.009	0.000
	Town & Fringe	421	-0.195	1.658	-0.354	-0.036	-2.411	0.016
	Village, Hamlet & Isolated Dwelling	1273	-0.885	2.033	-0.996	-0.773	-15.522	0.000
FE	Urban >10k	502	0.626	1.598	0.485	0.766	8.769	0.000
	Town & Fringe	38	-0.763	1.951	-1.404	-0.122	-2.411	0.021
	Village, Hamlet & Isolated Dwelling	110	-1.291	1.941	-1.658	-0.924	-6.975	0.000
Hospital	Urban >10k	5165	1.1955	2.072	1.138	1.252	41.459	0.000
	Town & Fringe	424	-0.241	2.299	-0.460	-0.211	-2.155	0.032
	Village, Hamlet & Isolated Dwelling	1275	-0.507	2.121	-0.624	-0.391	-8.545	0.000
Foodstore	Urban >10k	5175	0.127	0.699	0.108	0.146	13.103	0.000
	Town & Fringe	424	0.017	0.868	-0.066	0.099	0.392	0.696
	Village, Hamlet & Isolated Dwelling	1280	-0.735	1.650	-0.826	-0.645	-15.938	0.000
Primary School	Urban >10k	694	0.173	0.693	0.121	0.225	6.569	0.000
	Town & Fringe	50	0.100	0.505	-0.435	0.244	1.400	0.168
	Village, Hamlet & Isolated Dwelling	173	-0.289	1.072	-0.450	-0.128	-3.547	0.001
Secondary	Urban >10k	647	0.473	1.268	0.375	0.571	9.485	0.000

		N	Mean of differ ence	St. dev	confidence intervals		t	p
					lower	upper		
School	Town & Fringe	49	-0.673	1.505	-1.106	-0.241	-3.132	0.003
	Village, Hamlet & Isolated Dwelling	153	-1.190	2.092	-1.524	-0.855	-7.032	0.000

Table 6 shows there are significant differences between objective and subjective journey time measures, even within the urban-rural classifications, for urban and village, hamlet and isolated dwellings, but that in town and fringe areas the differences are not significant for primary schools and foodstores.

What is interesting from these analyses is the pattern in t -values. For urban areas the t values are all positive, implying that the $NTS > CAI$, whereas for Village, Hamlet and Isolated Dwellings, the values are all negative, implying that the $NTS < CAI$. For town and fringe the pattern is generally a decrease from positive to negative values moving through the urban – rural continuum. This therefore suggests that the geography of an area does impact the results. However, further analysis has shown similar patterns of longer journey times occurring where ($NTS < CAI$) and shorter journey times where ($NTS > CAI$) occur within these categories, and that there is still a significant difference between ($NTS > CAI$) and ($NTS < CAI$) *within* these categories, so the impact of journey time is relevant, even once scale is controlled for.

Splitting the analysis by journey time

This section explores this further by splittin the analysis by objective journey time category, thus enabling short journeys (<15mins) to be analysed separately as these may not be calculated accurately in the CAI dataset. This is because the minimum public transport journey time reported in the CAI is 10 minutes, any bus journey below this defaults to 10 minutes as it is deemed unrealistic that people would wait and board a bus for a journey less than 10 minutes. However, given the categorical nature of this analysis, the impact here should not be too large.

Table 7 – Dependant *t*-test results for difference between in journey time category between subjective (NTS) and objective (CAI) measures of journey time accessibility split by objective journey time category

	CAI category	N	Mean of differe nce	St. dev	confidence intervals		<i>t</i>	<i>p</i>
					lower	upper		
GP	<15 mins	5923	0.422	0.976	0.397	0.447	33.303	0.000
	16-20 mins	424	-0.632	0.895	-0.717	-0.547	-14.547	0.000
	21-30 mins	154	-1.396	1.190	-1.586	-1.207	-14.553	0.000
	31-40 mins	71	-2.479	1.132	-2.747	-2.211	-18.450	0.000
	41-60 mins	66	-3.727	0.714	-3.903	-3.552	-42.439	0.000
	60 mins +	210	-4.648	0.806	-4.757	-4.538	-83.515	0.000
FE	<15 mins	359	1.022	1.378	0.879	1.165	14.056	0.000
	16-20 mins	142	0.162	1.422	-0.074	0.398	1.357	0.177
	21-30 mins	81	-0.728	1.379	-1.033	-0.424	-4.756	0.000
	31-40 mins	36	-1.778	1.396	-2.250	-1.305	-7.640	0.000
	41-60 mins	18	-3.444	0.856	-3.870	-3.019	-17.080	0.000
	60 mins +	14	-4.429	0.938	-4.970	-3.887	-17.673	0.000
Hospital	<15 mins	2139	2.363	1.670	2.292	2.434	65.426	0.000
	16-20 mins	1839	1.264	1.700	1.187	1.342	31.899	0.000
	21-30 mins	1293	0.116	1.714	0.023	0.210	2.434	0.015
	31-40 mins	907	-0.774	1.645	-0.881	-0.667	-14.167	0.000
	41-60 mins	487	-1.784	1.652	-1.931	-1.637	-23.837	0.000
	60 mins +	199	-2.678	1.743	-2.922	-2.435	-21.679	0.000
Foodstore	<15 mins	6281	0.160	0.659	0.144	0.176	19.254	0.000
	16-20 mins	234	-0.876	0.576	-0.950	-0.802	-23.251	0.000
	21-30 mins	141	-1.681	1.030	-1.852	-1.509	-19.370	0.000
	31-40 mins	113	-2.858	0.549	-2.961	-2.756	-55.365	0.000
	41-60 mins	26	-3.808	0.801	-4.131	-3.484	-24.240	0.000
	60 mins +	84	-4.952	0.307	-5.019	-4.886	-	0.000
Primary School	<15 mins	870	0.175	0.669	0.130	0.219	7.698	0.000
	16-20 mins	22	-0.955	0.213	-1.049	-0.860	-21.000	0.000
	21-30 mins	16	-1.938	0.250	-2.071	-1.804	-31.000	0.000
	31-40 mins	6	-2.167	0.983	-3.198	-1.135	-5.398	0.003
	41-60 mins	3						
	60 mins +	0						
Secondary School	<15 mins	602	0.686	1.143	0.595	0.778	14.722	0.000
	16-20 mins	129	-0.364	1.053	-0.548	-0.181	-0.393	0.000
	21-30 mins	39	-1.282	1.255	-1.689	-0.875	-6.377	0.000

31-40 mins	27	-1.852	1.350	-2.386	-1.318	-7.126	0.000
41-60 mins	32	-3.063	1.496	-4.550	-3.150	-11.505	0.000
60 mins +	20	-3.850	1.500	-4.550	-3.150	-11.505	0.000

From

Table 7 the difference for journeys <15 minutes compared to longer journeys is clear from the positive t-values for shorter trips. Of course there could not be negative t-values where CAI<15 mins as this is the lowest category so a negative difference would be impossible, likewise where CAI>60 mins a positive difference would not be possible. While there is a significant difference between the datasets for all journey lengths, it is evident that where the CAI<15 minutes then (NTS>CAI) but where CAI>15 minutes then (NTS<CAI). This is true for all destination types except for Further Education and Hospitals where there are also positive t-values for longer journeys, up to 20 minutes (though statistically insignificant difference) for FE and 30 minutes for hospitals. This suggests that for short trips the subjective values are higher than would be expected from objective measures, which confirms earlier results, and that for longer trips subjective values are lower than would be expected from objective measures. However, what this analysis shows is that the difference between the datasets is statistically significant ($p<0.05$) across all destination types for each journey time category (except for FE 16-20 mins). However, the intervening categories all exhibiting the pattern of (NTS<CAI) supports the overall result. Likewise the analysis by geographical area supports the result that in urban areas (NTS>CAI) with a pattern towards (NTS<CAI) in more rural areas, where longer journey times would be expected.

In summary, these results show that there are statistically significant differences between the NTS and CAI values of journey time accessibility to a range of destinations at the postcode sector level. While errors can occur in the datasets due to calculation methods, even once this is controlled for, similar patterns emerge. When comparing across the journey time categories used it can be seen that in almost all cases (NTS<CAI), with the exception of short journey times less than 15 minutes where (NTS>CAI). The implications of these results and limitations of the approach will be discussed in the following section.

Discussion and Conclusions

The results have shown that there are statistically significant differences between objective (CAI) and subjective (NTS) understandings of accessibility. This is important, given that both

of these datasets are used by policy makers to make important decisions, and that both datasets are ultimately trying to represent the same thing: the accessibility of people to key services. It is therefore important to understand the differences between the datasets, and the implications of these for policy, and how such differences can be reduced.

As explained in the introduction, there are two expected reasons for differences in the datasets. Firstly errors in the Core Accessibility Indicators, either in the calculation method, in not measuring what is important in framing perceptions or if services “on the ground” differ from what is measured for example because of congestion, and secondly errors in the NTS responses, either as a result of sampling or data collection, or because of differences between how people perceive their (journey time) accessibility reality because of lack of knowledge, information, physical mobility problems, or built environment, amongst others. In reality the difference can probably be explained by a combination of these factors, with the “real” journey time accessibility falling somewhere in between subjective and objective measures of this.

Overall it can be seen that the subjective journey times are shorter than the objective journey times, except for shorter journeys, (those under 15 mins in CAI) where the NTS journey times are longer than the CAI dataset. This can be in part explained by calculation methods which mean that CAI journey times may not be accurate for shorter journeys and therefore may underestimate journey times. This highlights that use of the Core Accessibility Indicators must be with caution for short journey times, most likely in urban areas. However, the pattern of NTS journey times being less than CAI for longer trips is more difficult to explain. It would be expected that perceptions of accessibility would be greater than an objective measure, but the opposite seems to be the case. This could be as a result of the coarse scale of analysis, as little is known about the precise location of NTS responses within a large postcode sector, then the CAI value assigned is not as accurate as it could be, were more detailed geographic information known. For example, if the NTS responses are in quite central areas then the method of accounting for all SOA CAI values within a postcode sector may be an over-estimate of the NTS values. Alternatively it could be because the CAI values are average valued for the time achievable across an entire day, whereas NTS responses may relate to the minimum time a respondent thinks is achievable. This highlights a need for more accurate detail regarding perceptions or subjective measures of accessibility. Evidence from speaking with local accessibility planners suggests that in fact the core indicators are seen as

optimistic in more rural areas, so this highlights a discrepancy between this analysis and local knowledge which should be explored in more detail.

There is a general trend towards subjective journey times being greater than objective measures ($NTS > CAI$) in urban areas and shorter than objective measures ($NTS < CAI$) in rural areas, which can to some extent be explained by the calculation methods used.

The same general patterns occur across destination types, which is interesting and suggests that perceptions of journey time accessibility are not necessarily distinguishable to specific journey purposes, but may be a function of geography, individuals or socio-demographics, all of which could be further explored. There are however some interesting differences between journey purposes which are worth discussing. Table 3 shows that there is a smaller mean difference for Primary School, Secondary School and FE, which were the responses in the NTS that were limited to those with children attending school or college, so related to trips that are made on a frequent basis. Added to this the CAI destination datasets for primary schools in particular are of high quality, so the comparability of the NTS responses and CAI values for such destinations is understandable, and shows that where public perception is based on familiar journeys and the quality of the objective measure is good, then there is less difference between objective and subjective measures. As found by van Exel & Rietfeld (2009) unfamiliar journeys can result in differences of up to 46% between objective and subjective assessments of journey time, so these differences are to be expected for less familiar journey purposes such as hospitals. For destinations such as hospitals, GP and foodstores there are problems of destination definition which may account for some differences. For example, when asked where the nearest foodstore is, responses may vary between giving the nearest small food shop or the largest supermarket which is further away but the respondent may use. Hospitals again may have problems of differing definitions of hospitals for individuals and within the destinations used in calculating the Core Accessibility Indicators. Added to this is the fact that this may be an infrequent trip for many people, and differences are expected. Finally, GP show a relatively large mean difference, yet this might be unexpected given that a large proportion of people should be able to access a GP within a relatively short time. However, it may be that people respond to the survey question with how long it takes them to get to their GP, which may not necessarily be their nearest GP. This shows the importance of considering external factors, such as GP and school catchment areas, as well as services provided by hospitals and the size of supermarkets, which may mean that consideration of journey time to the *nearest* destination is not always appropriate.

There are a number of limitations in this approach, not least that this is focussed on time based measures of accessibility, and that there is a much broader range of factors that will account for accessibility. Additionally journey time measures are not the most robust measures of accessibility and there are others included in the CAI dataset, as shown in Figure 1, which provide much more opportunity for analysis, but given that the NTS data asked questions relating to time these could most directly be compared in this paper. While other factors such as choice or range of destinations available in the CAI dataset however could be used to account perceptions of accessibility, it is not thought these would necessarily be able to explain the discrepancies in journey time and therefore more data is first needed relating to perceptions of accessibility, both time and non-time related. There are also problems associated with the use categorical data is not as accurate as continuous data. This may mean that a difference in categories occurs when there is only a small difference in reported journey time (eg while journey times of 15 and 21 minutes would show up as 2 categories apart, a similar 6 minute difference could occur within one category). This was unavoidable in this work given the nature of the secondary datasets.

There is clearly a discrepancy between objective measures and subjective measures of journey time accessibility which this work has shown. However, there are some important limitations and gaps in understanding which prevent firm conclusions from being drawn. From this analysis it is difficult to unpick where there are real differences and where there are errors in the datasets. Either way, the difference is important and there is a need for further work to elicit why there is a difference. This highlights a need for more in depth understanding of perceptions, not just of time based accessibility, but accessibility overall which will encompass much more than just time based measures. Objective journey time is important, but it is not the only factor affecting accessibility, and other factors will play a part in influencing perceptions, both of journey time accessibility and accessibility more broadly. Pacione (1982) suggested that a linear relationship between objective and subjective measures of quality of life would mean that there was not a need for both, and that likewise the absence of such a relationship means that both objective and subjective measures are required. There is therefore a need both for more detailed data relating to perceptions of accessibility, as well as this being broadened to cover a variety of factors, not just journey time. This is something that further research as part of this PhD attempts to address, drawing on the strengths and learning from the limitations of existing data, many of which have been highlighted in this study. This will be undertaken through primary data collection in selected case study areas.

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