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Curl, A, Nelson, JD and Anable, J (2015) Same question, different answer: A comparison of GIS-based journey time accessibility with self-reported measures from the National Travel Survey in England. Computers, Environment and Urban Systems, 49. pp. 86-97. ISSN 0198-9715

https://doi.org/10.1016/j.compenvurbsys.2013.10.006

Author Version (post review)

For publication in: Computers, Environment and Urban Systems (2014)

Same question, different answer: A comparison of GIS-based journey time accessibility with self-reported measures from the National Travel Survey in England

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Abstract

Accessibility measures are usually designed to be objective representations of the 'real' conditions to provide a baseline for planning decisions and to track change over time. A wide range of approaches to measuring accessibility have been developed, usually based largely on quantifiable factors such as journey time. The simplest of these are based on the time taken to reach the nearest destination from an origin point. Destinations might include healthcare, education, employment or supermarkets, amongst others.

This paper posits that people's perceptions and experiences may differ from objectively measured conditions and crucially may be more important for understanding behaviour. An understanding of the difference between objective and subjective measures, and how they relate to each other is therefore vital before using either measure to inform policy decisions. This paper compares two approaches to measuring journey time accessibility to a range of destinations using objective measures of accessibility, calculated using GIS and individuals' self reported values, based on travel survey data.

Using two publically available datasets for England this paper explores the two approaches to measuring journey time accessibility to a range of destinations. Discordance between the two is found. Survey reported measures are found to be greater than objective measures in urban areas, but less in rural areas. This can be understood partly due to differences both between objective measures and reality and between perceptions and reality.

Keywords: Journey time; accessibility; Objective; subjective

1. Introduction

This paper presents results of exploratory data analysis undertaken to understand differences between objective and subjective measures of journey time accessibility to a range of local destinations using two published datasets in England. The datasets used are the National Travel Survey (NTS) and the Core Accessibility Indicators (CAI) which are commissioned by the Department for Transport (DfT).

In the context of transport planning accessibility has generally been understood to be the ability of people to access places, or places relative to the population, with transport as the main means by which this accessibility is provided, even for very short journeys where walking is the mode of transport. Geurs & 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* an*d services"* and by asking *"can people get to key services at reasonable cost, in reasonable time and with reasonable ease?"* (Social Exclusion Unit, 2003). This definition is increasingly adopted in more social studies of transport and is the one used to underpin a process of Accessibility Planning in the UK. Defining accessibility in this way presents a challenge in measurement as *'ease'* and *'reasonable'* will be interpreted differently depending upon the individual context. The process of Accessibility Planning in the UK represents one example of formalising an approach to measuring and applying the concept of accessibility within transport planning.

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 indicators for accessibility against which local authorities in England can benchmark. Measurement of accessibility and development of indicators such as the Core Accessibility Indicators (CAI) used in this paper support this process alongside tools such as 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).

In studies of accessibility, journey time is the basis for measurement and is usually calculated as travel time through the road or public transport network, often utilising GIS as a tool. Cumulative measures such as the origin and destination indicators reported in the CAI, are often used to give an indication of the number of people or destinations within certain time thresholds of a given point. These are used as targets against which performance is measured, for example in Local Transport Plan (LTP) "Accessibility Strategies". Whether or not such measures relate to individuals' experiences and/or perceptions of travel time remains relatively unexplored. This is problematic, particularly in the context of the focus of policy, such as Accessibility Planning, on individual experience and behaviour change which demand a focus on perceptions as well as the characteristics of the built environment, which objective measures seek to represent. This paper therefore presents a comparison of such GIS based journey time measures of accessibility with self-reported responses of journey time accessibility from a national travel survey. Although, as highlighted by the SEU, accessibility perceptions will rely on much more than journey time, this paper focuses specifically on understanding differences between objective and subjective journey time measures, and how these vary spatially and socially.

The paper is structured as follows: Section 2 provides a background to objective and subjective measurement of accessibility and also draws on examples from other fields. Reasons for expected differences between the two types of measure are explored theoretically and the implications of differences are discussed. Section 3 provides detail related to the datasets used for this analysis and then Section 4 outlines the methodology.

Results are presented in Section 5 and discussed in Section 6. The final section draws conclusions.

2. Background

Accessibility is a fundamental concept in transport planning and over time it has been defined and measured in numerous ways but is generally understood to be the ability for people to reach destinations. Accessibility is measured, in spatial and transport planning, using a range of objective measures designed to assess the level of accessibility provided by the transport and land use system, usually with the aim of improving accessibility for the population. Geurs and van Wee (2004) categorised measures of accessibility into four types: Infrastructure-based measures; Location-based measures; Person-based measures; and utility based measures. Each of these relies to some extent on a measure of journey time between two points, an origin and destination. Within location based measure, two types of measure: contour (or cumulative) measures and potential (or gravity) measures are the two most commonly employed within studies of accessibility. A contour measure is based on the number of opportunities accessible from a given origin or the population that can reach a given destination within a given time threshold. A potential, or gravity, measure is based on the work of Hansen (1959) and expresses accessibility of one origin or area relative to another, with destinations having a diminishing attractiveness with distance. The Core Accessibility Indicators (CAI), which are analysed in this paper, report simple infrastructure measures of the journey time between origins and their nearest destination as well as cumulative and gravity measures. More detail is given in Section 3.

While these measures are designed to represent the accessibility provided by the transport and land use system, they may not relate to individuals' experiences of accessibility. Recognition of a schism between objective measures and subjective understandings of accessibility is clearly not a new issue – Morris, Dumble & Wigan (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 (e.g. Parks, 1984).

While it can 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 (e.g. Diener & Suh, 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, Van Wee & Witlox (2010) give the case 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. This position is explained by Pacione (1982) for whom 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"*. However, this is not to say that objective measures do reflect the 'reality' of the built environment. It is likely that the reality falls somewhere between objective measures and subjective measures, due to errors in calculation or modelling assumptions. There are two reasons why differences between objective and subjective measures are expected. GIS model-based calculations of accessibility are prone to error, dependent upon the accuracy of input datasets and parameter assumptions, which may not be an accurate reflection of travel behaviour. While some, including Krizek, Horning & El-Geneidy (2012), cite perception “inaccuracy” as the primary reason for differences, it is important to recognise the limitation of model approaches and realise that these do not represent the objective “truth” although they may seek to do so.

Perceptions may differ from reality in two ways, firstly because of an individuals’ constraint, such as limited mobility which means that they differ from the average reality, but that their perception is their lived reality. Secondly, perception may differ due to lack of knowledge about available options or distorted perceptions due to familiarity with particular modes of transport.

In a recent review Van Acker, Van Wee & Witlox (2010) explain that while most empirical studies *“use objective variabl*es 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 t*o the objective reality”* (Van Acker at al, 2010). Exceptions include Lotfi & Koohsari (2009), Van Exel & Rietveld (2009) and Krizek, Horning & El-Geneidy (2012). 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. They find 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%. 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. In a more recent study, and most similar to this research, Krizek, Horning & El-Geneidy compare survey data with GIS modelled accessibility to a range of destinations (coffee shop, bank, bus/LRT stop and convenience stores) and find that differences occur in over 50% of cases.

In discussing variation in distance perception, Krizek, Horning and El-Geneidy (2012) describe three means by which this can be understood – subject-centred, stimulus-centred and subject/stimulus-centred factors which is an interaction of the two. Subject factors relate to characteristics of the individual such as age or income, which may affect how they perceive journey time. Stimulus-centred factors relate to characteristics of the environment. They describe the feature accumulation hypothesis (Sadalla & Staplin, 1980) as dominant in research on stimulus-centred factors, which is based on the assumption that the more complex an environment is the further or longer distances will be perceived as there is more information to process. Similiarly, although at a more micro scale, Bugmann & Coventry (2004) describe the segmentation hypothesis, whereby longer distances are psychologically compressed so that a straight line route will be perceived to be shorter than a route of the same distance with lots of turns, and which is therefore more complex, similar to the feature accumulation hypothesis. Route level detail is not explored in this paper, but can provide some explanation for where and why differences might occur. If differences between objective and subjective measures can be systematically understood according to such theories then a greater understanding of the relationships between objective accessibility, perceptions and travel behaviour can be achieved to enable planners to provide a transport system which provides a level of accessibility that will lead to a desired level of travel behaviour change.

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 as described in Section 3. Both these datasets contain information regarding the accessibility of key destinations. They approach measurement in different ways, the NTS being based on survey responses and the CAI on modelled journey times. These are both common approaches to measurement of concepts such as accessibility yet the two are rarely compared (McCrea, Shyy & Stimson, 2006; Lotfi & Koohsari, 2009; Van Acker, Van Wee & Witlox 2010). There is therefore little understanding of how subjective perceptions relate to objective measures. A greater understanding of the difference between the two approaches to measurement, 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.

This paper addresses this by comparing two types of journey time measures of accessibility to destinations.

3. Introduction to Datasets

The Core Accessibility Indicators (CAI) (DfT, 2011a) were originally calculated to support Local Authorities in England in developing an evidence base for accessibility strategies as part of the Local Transport Planning (LTP) process and to support two of the 198 National Indicators (NI)[1] against which Local Authorities may choose to report as part of their reporting to central government. Prior to the change of government in 2010 and the removal of the requirement for reporting against national indicators (LTT, 2011) this was the means by which central government managed the performance of local government. Since there is no longer a formal requirement for accessibility strategies or reporting of national targets, the indicators are produced to support local authorities in accessibility planning (DfT, 2011b), amongst a range of other potential uses such as promoting sustainable travel and travel planning which were identified by local authority officers involved in accessibility planning (Curl, Nelson & Anable, 2011).

Indicators have been calculated annually since 2005[2] using a GIS based accessibility model, originally developed for the Scottish Government in 1999 (Halden, McGuigan, Nisbet, & McKinnon, 2000) and further refined for DfT in 2003 (DHC & University of Westminster, 2003) using ACCALC software. In-depth details regarding the calculation methodology and input datasets are available elsewhere (DfT, 2011b). A range of accessibility indicators are produced; these can be categorised into Travel Time Indicators, Origin Indicators and

[1] NI175 - Access to Services and NI 176 - Access to Employment
[2] With the exception of 2006

Destination Indicators as illustrated in Figure 1. Calculations are undertaken at Census Output Area (COA)[3] level and aggregated to Lower Super Output Area (LSOA)[4] and Local Authority (LA)[5] levels for reporting.

Figure 1 about here

Figure 1 - Structure of the Core Accessibility Indicators (CAI).

Travel Time Indicators are infrastructure measures, which report the minimum journey time to the nearest destination for each LSOA, calculated as a population weighted average for all COAs within an LSOA. For example the nearest doctors surgery for a particular LSOA might be reported as five minutes by car, 15 minutes by public transport and 20 minutes by bicycle.

Figure 2 about here

Figure 2 – Mean journey times to the nearest destination type by public transport and car (CAI)

Figure 2 shows the mean public transport and car journey times to each destination across all LSOAs. The large variation around the mean minimum public transport journey time highlights potential problems with reporting a mean journey time for a regional local authority area which may not be an accurate reflection of the variation within that area. Similarly aggregating from COA to LSOA results in problems of aggregation since variation in size of COA, due to density, mean that differences may occur between urban and rural areas due to calculation methods. Using the population-weighted centroid as an origin point may under-estimate journey times for those living in outlying areas. This is more likely to be an issue in rural areas. Conversely journey times could be over-estimated for an individual living near to the boundary of a COA, but nearer to the destination in a neighbouring COA as their time will

[3] 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)
[4] Lower Super Output Areas (LSOA) 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) and will therefore vary in size depending upon population density. LSOAs are based on aggregation of COAs.
[5] 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/)

be calculated via the centriod. For car journey times (Figure 2) there is considerably less variation as shown by the smaller error bars. This graph suggests that the majority of LSOA are within 5 minutes of most destinations (hospitals and Further Education excepted) and that there is little variation around this mean.

Origin indicators are cumulative measures, which calculate the number of destinations accessible within a given time threshold from an origin point, in this case an output area. When aggregated these measures are a population weighted average of all output areas within a LSOA or LA, reported as cumulative measures. For example a measure might be the number of supermarkets accessible within 15 minutes of a given location.

Destination Indicators are cumulative measures, which relate to the number or proportion of the population that can access a destination within a given time threshold. Results report two time thresholds for each destination, a lower threshold of 15, 20 or 30 minutes, and an upper threshold of 30, 40 or 60 minutes depending on the destination[6]. These are cumulative measures and can be used to produce outputs such as '80% of the population can access a primary school by car within 15 minutes'.

The origin and destination measures described here are cumulative measures, reporting the number of destinations accessible within a given journey time threshold. They can also be described as contour measures. The CAI also report continuous accessibility measures based on Hansen's (1959) gravity model. These report the number of destinations or population accessible as a relative number, calculated using a distance decay function whereby fewer nearby destinations are more attractive than a greater number of more distant destinations.

Use of objective measures, such as the CAI, are problematic if the calculated objective measures do not correspond with users' perceptions of their journey time accessibility, which will influence their travel behaviour. The UK National Travel Survey (NTS)[7] contains questions pertaining to how long it takes for respondents to reach given destinations. This can be seen as a subjective measure as it is based on survey responses rather than objective measurement. This comparable data therefore provides the opportunity to understand results produced by two approaches to measuring the same outcome.

There are six destinations common to both of the datasets: **doctors, hospital, supermarket, primary school, secondary school and college.** These destinations are therefore used in this analysis. The following section describes the methodology used to match the CAI and NTS datasets and then analyses comparing the two are presented.

4. Methodology

The two datasets are matched geographically in order to undertake an analysis of the difference between objective and subjective measures of time-based accessibility using available existing datasets. Data for 2007 and 2008 were extracted from NTS as this was the

[6] The lower threshold is 15 minutes for supermarket, town centre, primary school and doctor, 20 minutes for secondary school and employment and 30 minutes for hospitals and further education. The upper threshold is 30 minutes for supermarket, town centre, primary school and doctor, 40 minutes for secondary school and employment and 60 minutes for hospitals and further education.

[7] The National Travel Survey (DfT, 2010a) is a UK-wide continuous household survey (since 1988) on personal travel.

most recent data available at the time of analysis and the CAI for the appropriate year were attached to the NTS dataset following the methodology described here.

The level of geography of the two datasets is different so a vital first step is to match the two datasets together. The CAI are reported at Lower Super Output Area (LSOA) and the lowest level of geography available from the NTS is the postcode sector. This was provided as a custom dataset by the DfT as the standard data is available at a much coarser regional level. Postcode sector level is the lowest level at which the DfT were able to provide the NTS data, due to their sampling procedures, which are based around postcode sectors. This means that household, postcode or street level data, which would enhance this analysis, is not available. LSOA contain an average of 1500 people (min: 1000 people=400 households)[8] and will therefore vary in geographical extent 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 postcodes[9]; these will vary in size with population density. The two units of geography do not fit neatly together, so while postcode sectors are larger than LSOA the boundaries overlap. Each postcode sector contains an average of 14 (min: 1; max: 41) LSOA and each LSOA falls into an average of 3 (max: 26; min: 1) postcode sectors. 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 resulting in potential errors or loss of data. This is known 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 dependent on the units to which the data are aggregated (Fotheringham, Brunsden & Charlton, 2001). CAI at LSOA level are population weighted means aggregated from COA level. Further aggregating to postcode sector can potentially lead to greater errors. To avoid aggregation, one option would be to follow a point in polygon process of allocation and match the data based on the LSOA within which the postcode centroid falls or vice versa. However, the resultant loss of data would be large and taking the centre point of an area as large as a postcode sector increases the potential level of error as it ignores the variation of CAI values within each postcode sector.

Therefore, in order to be as accurate as possible in this analysis, polygon to polygon matching was used to aggregate CAI values to postcode sector level by calculating a weighted value of CAI journey time based upon the proportion of each postcode sector covered by each LSOA, representing the range of CAI results within any given postcode sector proportional to the overlap. The matching was undertaken using MapInfo v6. The combined dataset is therefore based on postcode sectors as the primary unit of analysis and consists of individual NTS household responses with additional CAI journey time measurements attached for each of the six destination types.

Responses to the National Travel Survey (NTS) questions are coded into categories at the point of interview meaning raw reported journey times are not available. For the purposes of this comparison, the CAI were coded into the same categories and the analysis compares the difference between the response categories for the two datasets.

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[8] http://www.neighbourhood.statistics.gov.uk/dissemination/Info.do?page=aboutneighbourhood/geography/superoutputareas/soafaq/soa-faq.htm (Accessed: 27/05/2010)
[9] http://www.statistics.gov.uk/geography/postal_geog.asp (Accessed: 27/05/2010)

5. Results

An overview of the distribution of the NTS (Figure 3) and CAI (Figure 4) datasets shows similar patterns. In both cases over 50% of cases of LSOA have a mean journey time of 15 minutes or less, by public transport and/or walk, to all destinations except for hospitals and very few cases fall into the greater than 60 minutes category.

Despite the patterns being similar there are clear differences in the actual proportions in each category. In Figure 4 the proportion of each destination type falling into the <15mins category is much greater than in Figure 3. For example, over 80% of LSOA in the case of doctors, and almost 100% for shopping centre and primary schools have a mean journey time of less than 15 minutes whereas these are much lower for NTS postcode sectors. On the contrary there are larger proportions of NTS postcode sectors falling into the longer journey time categories, across all destination types.

Figure 3 about here

Figure 3 - NTS reported journey times to nearest destination by PT/walk

Figure 4 about here

Figure 4 - CAI journey times to nearest destination by PT/walk

This suggests that at an aggregate level CAI journey times to destinations are lower than NTS journey times. However, this shows the general trend across the aggregate national datasets and is not a like for like comparison of the two datasets for a given case (NTS) or geographical area. It could be that the NTS responses are not an accurate geographical reflection and so the journey times are longer because they are concentrated in rural areas for example. By matching the data geographically more robust comparisons based on actual differences in a paired dataset can be made.

Figure 5 illustrates the number of cases where differences occur between objective and subjective measures, categorised by: no difference, CAI<NTS and CAI>NTS.

A negative difference (NTS-CAI) indicates that the NTS response category is lower than the CAI journey time meaning that the NTS is an underestimate of the CAI, so survey responses are lower than modelled journey time accessibility. A positive difference means that the NTS is an underestimate of the CAI, so journey time reported by survey respondents is greater than modelled journey time accessibility. Differences between objective and subjective measures occur across destination types, although differences occur more often for hospitals and colleges. There are differences amongst destinations in terms of whether the CAI is greater or less than the NTS journey time to a destination.

Figure 5 about here

Figure 5 - Proportion of cases (NTS) where the difference in journey time category with the CAI is zero, positive or negative

For doctors, supermarkets and primary schools there is no difference in the journey time category in over 50% of cases. Differences are more common for hospitals, secondary schools and colleges. When there is a difference this is more often an underestimation of journey time by the CAI (positive difference) for all destinations except supermarket. For supermarkets CAI is more likely to overestimate the journey time relative to NTS responses. This is potentially due to differences in the definition of a supermarket, although given that the CAI includes small food stores it would be expected that the opposite would be the case and that the CAI journey times may be significantly lower than NTS responses. Wilcoxon signed rank tests confirm that the difference between the subjective and objective journey time categories are significant ($p<0.01$) for all destinations.

In order to explore what factors might explain differences between objective and subjective measures, further analyses are undertaken to understand how the differences vary dependent upon the absolute CAI journey time, across rural and urban areas, compared with cumulative accessibility measures and demographic data.

Although the NTS data is categorical, CAI data is continuous meaning the differences between the two datasets can be analysed in terms of journey time in order to establish whether differences are more likely over longer or shorter journeys.

Figure 6 shows the mean CAI journey time for cases where the difference is positive, negative or no difference, across destinations. One-way ANOVAs (not reported) confirm that journey time (CAI) varies significantly across categories of difference (i.e. no difference, positive, negative) for all destinations.

Figure 6 about here

Figure 6 - Mean CAI journey time when the difference between CAI and NTS falls into the category shows on x-axis

Objective (CAI) journey times are shortest when there is no difference between the two measures, except for hospitals, suggesting that for shorter journey times there is a greater level of agreement between the two types of measure. Objective journey times are longer when they are an over-estimate of subjective journey times and vice versa.

In order to assess the relationship of these results to location, further analysis compares results in relation to the urban/rural classification used by the Department for the Environment Food and Rural Affairs (Defra). Different patterns might be expected in urban and rural areas both due to differences in perceptions of accessibility and also because of different types of errors occurring in CAI calculations, for example due to the size of output areas in rural areas.

The rural-urban definition is a categorisation used by Defra and categorises LSOAs into: Urban (>10k population); Town and Fringe; and Village, Hamlet and Isolated Dwellings, based upon population density. 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 LSOA or postcode sectors could have different errors within the CAI dataset, to smaller urban LSOA.

Chi-squared tests confirm that the influence of geographical area is significant in influencing the difference between self-reported (NTS) and modelled (CAI) measures of journey time accessibility to destinations:

- Doctor: χ^2 (10) = 11667, $p<0.01$
- College: χ^2 (10) = 356, $p<0.01$
- Secondary School: χ^2 (10) = 617, $p<0.01$
- Primary School: χ^2 (8) = 944, $p<0.01$
- Hospital: χ^2 (10) = 2095, $p<0.01$
- Supermarket: χ^2 (10) = 13504, $p<0.01$

Odds ratios are a useful way of presenting differences in categorical data and for showing the effect size (Field, 2009). Figure 7 shows the odds of there being a difference between objective and subjective journey time categories for each of the three sub-categories of rurality, compared to the other two categories. Odds above 1 indicate that there is more likely to be a difference in the urban-rural category shown, compared with the other two categories, whereas if the odds are less than one there is less chance of there being a difference. For example, for supermarkets differences occur seven times more frequently in villages than in urban or town and fringe areas. Differences are more likely in rural areas across all destination types.

Figure 7 about here

Figure 7 - Odds of there being a difference between NTS and CAI

Taking only those cases where there is a difference, Figure 8 shows the odds of this difference being negative (CAI>NTS) and therefore the CAI overestimating the journey time relative to the NTS. The low odds in urban areas show that in these areas the CAI is more frequently an underestimate of journey times by NTS whereas in rural areas the opposite is true and self-reported journey times are usually lower than the CAI.

Figure 8 about here

Figure 8 – Odds of CAI being greater than NTS (overestimation of journey time)

A measure of journey time accessibility to the nearest destination of each type, used thus far, is the simplest type of accessibility measure. As outlined in Figure 1, the CAI also cumulative accessibility measures. The origin indicators measure the number of destinations accessible within a lower and upper time threshold of each LSOA and a continuous or gravity measure of accessibility based on a distance decay function which can therefore be seen as a measure of destination density. Following the same aggregation procedure as for journey time measures, three origin measures were calculated for each postcode sector and are compared with the differences in journey time measures in Table 1. The upper and lower time thresholds vary dependent upon the destination[10]. It may be that the density of destinations affects the likelihood of there being a difference between objective and subjective measures because a wider range of destinations or living near to more destinations may improve the perception of accessibility.

[10] Doctor 15/30 mins; Hospital 30/60 mins; Supermarket 15/30 mins;Primary School 15/30 mins; Secondary School 20/40 mins; College 30/60 mins.

Table 1 – Mean number of destinations accessible within lower & upper time thresholds and mean value of gravity measure compared with the difference between objective and subjective JT measures

Mean number of destinations accessible within lower time threshold compared with the difference between objective and subjective JT measures

	No difference	**Difference**	**CAI < NTS**	**CAI > NTS**
Doctor	3.3345	2.4347	2.6587	2.1527
Hospital	1.951	1.6943	1.8465	1.3424
Supermarket	4.6449	4.781	4.2293	5.1223
Primary School	4.1187	3.8616	3.6773	4.242
Secondary School	2.6494	1.8916	2.2239	1.462
College	4.5565	3.2099	3.933	2.1727

Mean number of destinations accessible within upper time threshold compared with the difference between objective and subjective JT measures

	No difference	**Difference**	**CAI < NTS**	**CAI > NTS**
Doctor	4.6232	4.5343	4.3939	4.711
Hospital	4.1011	3.8815	3.9338	3.7605
Supermarket	5.0491	6.0552	5.0981	6.6474
Primary School	4.9939	5.7144	4.8897	7.4165
Secondary School	4.463	4.1477	4.263	3.9985
College	8.3532	7.6355	8.0855	6.99

Mean value of gravity measure compared with the difference between objective and subjective JT measures

	No difference	**Difference**	**CAI < NTS**	**CAI > NTS**
Doctor	1.9008	1.4307	1.5264	1.3101
Hospital	1.0212	0.8632	0.9208	0.7299
Supermarket	4.7957	5.5567	4.7125	6.0791
Primary School	1.6204	1.594	1.4521	1.8869
Secondary School	1.7282	1.4527	1.558	1.3166
College	3.7749	3.142	3.4291	2.7302

In general there are fewer destinations of each type accessible when a respondent reported JT differs from the CAI, with the exception of Supermarkets. This can be expected following the previous analysis, given that differences are more likely in rural areas, with longer journey times, and therefore fewer destinations are likely to be accessible. However, the pattern becomes less clear when comparing the direction in which the difference occurs with the number of destinations accessible. In some cases fewer destinations are accessible when the CAI>NTS and in some cases the opposite is true, with the pattern differing between upper and lower thresholds. However, for the gravity accessibility measure the pattern is clearer and as expected fewer destinations are accessible when the CAI>NTS (more common in rural areas) than when the CAI<NTS, with the exception of supermarkets, similar to previously found. Given that this measure might be seen to be a more robust measure of accessibility, less sensitive to time thresholds this is used in the following section, which models the influence of social and spatial factors in predicting a difference between objective and subjective measures.

Separate binary logistic regression models were estimated for each destination, firstly to predict cases where there is a difference between objective and subjective measures of journey time accessibility, and secondly to predict the direction of this difference, where it occurs. This allows us to see which socio-spatial factors are most strongly associated with discrepancies between objective and subjective accessibility. The selection of covariates in the models is based on existing knowledge regarding factors which may be related to perceptions of accessibility as well as the availability of variables in the datasets used.

Journey time to nearest destination is included as a measure of whether those who live closer to destinations are more likely to experiences differences with objective measures. As already identified in this paper there is a relationship between the (objective) journey time and the differences between measures. Potential accessibility relates to the destination density and can be seen as a robust measure of accessibility. It is included in addition to journey time as it may be that the density and availability of destinations affects perceptions of accessibility more than the journey time itself. The urban/rural categorisation described above was also included. Further to the environmental variables already described, six demographic variables are included to understand whether individual difference can account for differences in perception and objective measures. It is likely that perceptions and indeed capabilities will differ with age. Age is only available as categorical data in the raw dataset. Therefore, based on observation of descriptive statistics and because an elderly age group is most likely to experience accessibility differently to that which is measured, a binary variable indicating those over 60 was used. Respondent sex was included as it is likely that males and females will perceive journey time differently (Krizek, Horning & El-Geneidy, 2012). Ethnicity is also included as a control variable. The raw data does not include a measure of household income, which may also be an important explanatory variable. As an alternative socio-demographic group was considered, but there were not differences across categories in the descriptive analysis so this was not included in the final model. Main car driver and frequent bus user were included as measures of familiarity with mode. Following the findings of van Exel and Rietveld (2009) it is expected that those familiar with a mode (in this case public transport) are more likely to be aware of how long it takes to travel using that mode. Those experiencing mobility difficulties may take longer to travel to destinations and therefore it is expected that the CAI is more likely to underestimate journey times for these people.

Table 2 - Logistic Regression Model Results (Dependent variable: difference between CAI and NTS).

	Doctors		Hospital		Supermarket		Primary School		Secondary School		College	
	β (SE)	Exp(β) (CI)	β (SE)	Exp(β) (CI)	β (SE)	Exp(β) (CI)	β (SE)	Exp(β) (CI)	β (SE)	Exp(β) (CI)	β (SE)	Exp(β) (CI)
JT to nearest	**0.164(0.005)****	1.179(1.167,1.191)	**-0.003(0.001)***	0.997(0.994,1)	**0.381(0.01)****	1.464(1.434,1.494)	**0.373(0.042)****	1.452(1.338,1.577)	**0.118(0.016)****	1.125(1.09,1.162)	**0.096(0.014)****	1.1(1.07,1.132)
Potential accessibility	0(0.017)	1(0.967,1.034)	**-0.309(0.048)****	0.734(0.668,0.807)	**0.042(0.02)***	1.042(1.003,1.083)	**-0.586(0.206)****	0.556(0.371,0.834)	-0.036(0.119)	0.965(0.765,1.217)	-0.046(0.062)	0.955(0.846,1.078)
Urban	-0.112(0.078)	0.894(0.767,1.043)	**-0.545(0.118)****	0.58(0.46,0.731)	-0.165(0.111)	0.847(0.682,1.054)	0.549(0.439)	1.732(0.732,4.097)	0.176(0.289)	1.192(0.676,2.102)	-0.246(0.369)	0.782(0.379,1.613)
Rural	**0.268(0.087)****	1.308(1.103,1.55)	-0.057(0.135)	0.945(0.725,1.231)	0.195(0.114)	1.215(0.972,1.518)	-0.065(0.442)	0.937(0.394,2.229)	0.587(0.346)	1.799(0.913,3.543)	-0.568(0.433)	0.567(0.242,1.325)
Age (over 60)	**0.153(0.05)****	1.165(1.057,1.285)	-0.056(0.064)	0.946(0.835,1.071)	**0.403(0.076)****	1.496(1.289,1.737)	0.352(0.573)	1.422(0.463,4.37)	-0.473(0.372)	0.623(0.301,1.291)	-0.246(0.36)	0.782(0.386,1.582)
Sex (Female)	-0.081(0.048)	0.923(0.84,1.014)	0.08(0.062)	1.084(0.961,1.223)	0.134(0.074)	1.143(0.989,1.322)	0.405(0.269)	1.499(0.885,2.538)	-0.037(0.173)	0.964(0.686,1.353)	0.024(0.207)	1.024(0.683,1.535)
Ethnicity (non-white)	0.079(0.095)	1.082(0.899,1.302)	-0.252(0.103)	0.777(0.635,0.951)	0.161(0.16)	1.174(0.858,1.608)	0.386(0.39)	1.471(0.685,3.159)	-0.635(0.295)	0.53(0.297,0.945)	0.102(0.304)	1.107(0.61,2.008)
Main car driver	0.094(0.053)	1.098(0.991,1.218)	-0.037(0.066)	0.964(0.847,1.098)	0.128(0.083)	1.137(0.966,1.338)	-0.278(0.282)	0.757(0.436,1.316)	0.001(0.186)	1.001(0.695,1.441)	-0.122(0.227)	0.885(0.567,1.38)
Frequent bus user (> 1/month)	**-0.214(0.054)****	0.808(0.726,0.898)	-0.014(0.068)	0.986(0.862,1.127)	**-0.378(0.088)****	0.685(0.577,0.814)	-0.494(0.33)	0.61(0.32,1.164)	-0.011(0.209)	0.989(0.657,1.488)	**-0.482(0.243)***	0.617(0.384,0.994)
Mobility difficulties	**0.199(0.065)****	1.22(1.073,1.386)	0.028(0.086)	1.028(0.869,1.216)	0.164(0.1)	1.178(0.968,1.434)	-1.607(0.842)	0.201(0.038,1.045)	0.382(0.317)	1.465(0.787,2.728)	-0.135(0.359)	0.874(0.432,1.766)
Constant	-2.77(0.118)**		1.784(0.143)**		-6.262(0.186)**		-4.273(0.634)**		-1.766(0.45)**		-0.594(0.528)	
N	12544		6302		12611		810		769		566	
R^2 (Nagelkerke)	0.363		0.031		0.609		0.366		0.257		0.215	

** p<0.01, * p<0.05

Table 3 - Logistic Regression Model Results (Dependent variable: CAI is greater than NTS).

	Doctors		Hospital		Supermarket		Secondary School		College	
	β (SE)	Exp(β) (CI)	β (SE)	Exp(β) (CI)	β (SE)	Exp(β) (CI)	β (SE)	Exp(β) (CI)	β (SE)	Exp(β) (CI)
JT to nearest	**0.273(0.009)****	1.314(1.289,1.338)	**0.108(0.004)****	1.114(1.105,1.123)	**0.31(0.017)****	1.364(1.319,1.41)	**0.283(0.033)****	1.327(1.243,1.417)	**0.177(0.022)****	1.194(1.143,1.247)
Potential accessibility	**0.099(0.032)****	1.104(1.037,1.175)	**0.374(0.075)****	1.453(1.255,1.682)	**0.224(0.036)****	1.251(1.167,1.342)	0.307(0.186)	1.36(0.944,1.959)	-0.008(0.101)	0.992(0.815,1.209)
Urban	-0.16(0.141)	0.852(0.646,1.124)	**0.371(0.139)****	1.45(1.104,1.904)	0.212(0.218)	1.236(0.807,1.894)	-0.387(0.467)	0.679(0.272,1.697)	0.383(0.497)	1.467(0.554,3.885)
Rural	**-0.562(0.143)****	0.57(0.431,0.754)	-0.1(0.156)	0.905(0.667,1.229)	-0.082(0.196)	0.921(0.627,1.353)	0.054(0.507)	1.056(0.391,2.85)	0.295(0.572)	1.343(0.438,4.121)
Age (over 60)	**-0.318(0.1)****	0.728(0.598,0.886)	-0.163(0.087)	0.849(0.716,1.008)	**-0.414(0.141)****	0.661(0.502,0.871)	-0.255(0.746)	0.775(0.18,3.339)	0.237(0.652)	1.267(0.353,4.551)
Sex (Female)	-0.216(0.1)	0.806(0.663,0.98)	0.038(0.084)	1.039(0.882,1.225)	-0.117(0.139)	0.889(0.677,1.169)	-0.318(0.347)	0.728(0.369,1.436)	-0.266(0.356)	0.766(0.382,1.538)
Ethncity (non-white)	-0.028(0.229)	0.972(0.62,1.524)	0.091(0.15)	1.096(0.816,1.471)	-0.001(0.362)	0.999(0.492,2.031)	0.147(0.784)	1.159(0.249,5.383)	-0.522(0.62)	0.593(0.176,1.999)
Main car driver	**-0.218(0.108)***	0.804(0.65,0.993)	0.065(0.091)	1.067(0.893,1.275)	-0.023(0.16)	0.977(0.714,1.337)	-0.5(0.358)	0.607(0.301,1.223)	0.373(0.376)	1.452(0.695,3.036)
Frequent bus user (> 1/month)	**0.424(0.114)****	1.528(1.222,1.909)	0.161(0.095)	1.174(0.975,1.414)	0.342(0.178)	1.407(0.993,1.994)	-0.247(0.44)	0.781(0.33,1.849)	-0.09(0.419)	0.914(0.403,2.077)
Mobility difficulties	-0.13(0.137)	0.878(0.671,1.15)	-0.236(0.121)	0.79(0.623,1.001)	-0.222(0.196)	0.801(0.545,1.177)	-0.655(0.741)	0.519(0.121,2.22)	-1.003(0.834)	0.367(0.072,1.88)
Constant	-4.56(0.229)**		-4.244(0.21)**		-5.59(0.366)**		-4.879(0.818)**		-4.341(0.865)**	
N	4208		4556		2243		387		325	
R^2 (Nagelkerke)	0.64		0.395		0.638		0.619		0.532	

** p<0.01, * p<0.05

Supporting earlier analyses the logistic regression models highlight the importance of journey time in explaining differences between objective and subjective measures. In all cases, longer journey times are associated with a difference and with this difference being an overestimate by the CAI compared with NTS responses. However, the models also show the importance of other variables, differentiated across destinations.

As expected a lower destination density, rurality and older age are also significant in explaining differences for some destinations. On the other hand being a bus user, living in an urban area, and perhaps surprisingly mobility difficulties are negatively associated with differences between objective and subjective measures, meaning that these individuals are more likely to have reported journey times falling into the same category as the CAI measures.

Table 3 shows that the objective measure (CAI) is an over-estimate of self-reported journey times (NTS) when journey times are longer, greater destination density, when the respondent is under 60, not a main car driver, but is a bus user. Having mobility difficulties is significant for some destinations in predicting greater self-reported journey times. Women reported longer journey times than in the CAI for the majority of destinations and this is significant for doctors. A model could not be estimated for the direction of difference for primary schools, given the small number of cases.

Results have explored where and for whom differences occur between objective and subjective measures and also the nature of the difference between the two measures. These are discussed further in the following section.

6. Discussion

The results show that there are significant differences between objective (CAI) and subjective (NTS) measures of accessibility. This is important, given that both of these datasets are used for decision making in policy, 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, the implications of these for policy, and how such differences can be reduced.

Overall, objective (CAI) journey times are shorter than the subjective (NTS) journey times, except for supermarkets where the CAI measures are larger than NTS. Differences are more likely to occur in rural areas, but in rural areas the pattern is reversed and NTS journey times are shorter than in the CAI. 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.

The same general patterns are observed across destination types, suggesting 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 differences between journey purposes. For example, primary schools and secondary schools exhibit less difference. These responses were limited in the NTS to those with children attending school so are related to trips that are made on a frequent basis. Furthermore the CAI destination datasets for primary schools in particular are of high quality, so the comparability of the NTS responses and CAI values for primary schools suggests that where public perception is based on familiar journeys and the quality of the objective measure is good, there is less difference between objective and subjective measures.

Van Exel & Rietveld (2009) found that 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, doctors and supermarkets there are problems of destination definition which may account for some differences. For example, when asked where the nearest supermarket is, responses may vary between giving the nearest small food shop or the largest supermarket which is further away but which the respondent may use. There may also be differing definitions of hospitals for individuals and within the destinations used in calculating the Core Accessibility Indicators. Furthermore, hospital trips may be infrequent for many people. This shows the importance of considering external factors, such as doctors' 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.

Differences occur between urban and rural areas, and with journey length. In general objective measures under-report perceived journey time in urban areas and for shorter journeys and over-report perceived journey time in rural areas and for longer journeys. There are several possible explanations for this including the segmentation hypothesis (Bugmann and Coventry, 2004) and the accumulation hypothesis (Sadalla and Stapling, 1980; Krizek, Horning & El-Geneidy, 2012) in suggesting that longer journeys may be psychologically compressed relative to shorter journeys and therefore longer journeys are underestimated in NTS relative to the CAI compared to over-estimation of shorter journeys.

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. Journey times are likely to fluctuate more in urban areas due to congestions levels and in rural areas it is possible that speed limits are more likely to be exceeded and therefore perceived or actual achieved journey time is less than that assumed by a measure restricted by the speed limit. Further explanations arise from the coarse scale of analysis. The precise location of NTS responses within a large postcode sector is unknown. This affects the results, for example, if the NTS responses are centrally located within a postcode sector then the method of accounting for all LSOA CAI values within a postcode sector may be an over-estimate of the NTS values. This highlights a need for more accurate detail regarding perceptions or subjective measures of accessibility. Evidence from speaking with local accessibility planners (Curl, Nelson & Anable, 2011) suggests that in fact the core indicators are seen as optimistic in more rural areas, so our analysis is at odds with local knowledge.

This highlights a potential problem with national level indicators. The importance of local level indicators is highlighted by Holden (2009) *"The democratic potential of indicators work* is slighted by those who promote the use of standard, comparable indicators, with the *laudable goals of minimising work"* (p.439). This suggests that the drive for national level datasets may not be appropriate and in fact efforts may be best placed to develop robust measures at a local level. Neither of the datasets make distinction between urban and rural areas in terms of thresholds of journey time accessibility (DfT, 2011c), or indeed destination types or modes of transport. This is an important point as expectations, and indeed desired accessibility may be less in rural areas (Farrington & Farrington 2005). Some of these differences could be due to the nature of calculations, which will give different results dependent upon the size of the zone calculated. The differing size of census output areas (COA) in urban and rural areas means that there is a much greater potential for inaccuracies in rural areas. The indicators are calculated from the centroid of each COA. This means that for larger COA (in rural areas) the potential for error is greater as individual households will be a greater distance from the centroid. This could lead to the indicators underestimating journey times as it does not account for the distance of the household from the centre of the LSOA. There is also potential for overestimating journey time. This could happen if a household is near to a town centre offering essential destinations, yet in a different COA to the town centre as the algorithm would calculate the journey time via the centroid of the COA within which the household falls. This shows the vulnerability of the indicators to geographical boundaries and is illustrative of the Modifiable Areal Unit Problem (Openshaw and Taylor, 1981) whereby geographical measures could produce vastly differing results if boundaries are changed. Similarly, the use of categorical responses and large postcode sectors as the unit of analysis limits the utility of the NTS in analysing individual level data.

This analysis has highlighted some patterns in differences between a subjective and objective approach to measuring journey time accessibility to destinations in national datasets. However, given the coarse scale of analysis, care in interpreting the results is needed as a difference in category could range from two minutes to 40 minutes. Furthermore, zonal level analyses are open to issues of spatial aggregation. The CAI measures, calculated at the zonal level, are likely to be prone to error due to differences in size.

There is clearly a discrepancy between objective measures and subjective measures of journey time accessibility. However, there are some important limitations and gaps in understanding which prevent firm conclusions from being drawn, not least that differences may be as much to do with the way in which data are collected and measures calculated than any firm differences between perceptions and reality. From this analysis it is difficult to unpick where there are real differences and where there are errors in the datasets. Nonetheless, the difference is important and there is a need for further work to elicit why there is a difference and to understand the implications of measurement techniques. Both of these datasets are currently used by policy makers and planners to measure accessibility to a range of services, yet they produce different results. Therefore, whether or not the differences identified here are attributable to any actual difference, or issues of data, consideration needs to be given to how and why such measures are produced, and what implications using each measure might have. The DfT has recently concluded that GPS-based measurement is not an appropriate means of data collection to replace travel diary data, following a pilot study which produced vastly different results (DfT, 2012; LTT, 2012). This suggests that the way in which people record and report their travel activity is vastly different from what they actually do when it is objectively recorded using GPS (although potential errors in GPS recording should be taken into account). Clearly a change in methodology could have implications for policy outcomes, if assumptions upon which policy has been based change.

Some consideration should be given to the phrasing of survey questions and calculation of indicators in future. Given the proximity of some destinations such as doctors and primary schools greater differentiation between areas could be highlighted through use of walk-based accessibility measures and including walk journeys under 1 mile in the NTS. Walking is included in the calculations and survey responses to connect to the public transport system but not as a mode in its own right, unless the walk time is shorter than the public transport time, meaning it is not possible to ascertain whether the result relates to public transport and walk or walk only. Such an approach is not a reflection of reality because while a public transport trip may be shorter than walking it does not mean that this provides a better level of accessibility than walking, as perceptions of accessibility, and subsequently behaviour is likely to be affected by much more complicated reasoning dependent on the extent of the difference in time between the public transport and walk trip. For example, someone is unlikely to walk 10 minutes in the wrong direction, then get on a bus for 5 minutes, for a journey that would take 16 minutes to walk yet the way in which the datasets are currently constructed would give a 15 minute public transport journey time and not report the walk time.

Cumulative and gravity accessibility models rely on objective journey time measures of separation between origins and destinations. If these objective measures are inaccurate in relation to perceptions, as suggested by this analysis, then their reliability as the basis for policy decisions must be brought into question. If perceptions, upon which behaviour is based, differ from objective measures, then changes to accessibility, brought about through analysing objective measures may not lead to the desired change in behaviour. For example, fewer destinations will be accessible within given thresholds if the time taken to cover the same distance is greater than that assumed. This could have consequences for policies such as Accessibility Planning which rely on measuring the numbers of destinations accessible within given journey times and aim to change this. That is not to say that accessibility measures should be based only upon subjective measures of journey time, as this leads to issues of whose perceptions are taken into account, but rather that an approach utilising both should be considered, especially where differences are likely to be significant.

7. Conclusions

Since the introduction of Accessibility Planning in the UK, cumulative measures of accessibility are increasingly used by local transport planners. However, there is limited consideration of how objective measurement compares with subjective measures of accessibility.

The results of this comparison are useful in the context of two different methodological approaches to collecting the same data. 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 in this analysis the CAI data are regarded as an objective measure, based upon the location of services and the transport networks, whilst the NTS data are 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.

The results suggest that differences are a geographical problem as much as a conceptual one. Either way, there needs to be greater policy recognition of the differences between objective and subjective measures. Assuming area wide measures apply to the individual and vice versa, in the case of NTS, is problematic and this is highlighted by the results.

While there are numerous potential pitfalls with the use of such data, they also clearly present great opportunity given the rich level of data available which does not exist elsewhere. It should be acknowledged that the CAI are produced based on the best available data and evidence and are continually improving. The DfT acknowledges that best practice in this area is evolving (Lloyd and Moyce, 2012) and there are lessons to be learnt, to which the results presented here can contribute.

A limitation of this research is the use of categorical response variables in the NTS which limits the analytical capability. Furthermore, it is not known which specific destination respondents are referring to when they answer and this may differ from the dataset used in objective measures. Both of these were recognised by Krizek, Horning and El-Geneidy (2012) who suggest a need to ask respondents to identify which destination they usually visit and give the time taken in minutes, rather than a categorical response. Such an approach was used as a further stage of the doctoral research presented (Curl, 2013) here.

While the results do not systematically show for whom, or where differences between objective and subjective measures occur, there are some patterns across destinations and types of geographic area. The important message is that there are differences and that these vary both spatially and socially. More research is needed to understand differences more clearly and how these can be accounted for given that so much accessibility modelling depends upon objective journey time measures for the average person, yet individuals' perceptions, upon which their behaviour is based, vary significantly. Therefore although we cannot say in any absolute terms what the differences between the two types of measurement are, it is important to recognise and acknowledge that there are differences and further research is needed to build on the results presented in this paper.

While recognising the importance of subjective measures, it is also necessary to remember the value of objective measurements, and their importance in policy development. 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 (Stanley & Vella-Brodrick 2009). 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 might therefore be best placed to deepen our understanding of accessibility and enable interventions to be appropriately targeted.

Acknowledgements

This paper is based on research undertaken as part of the PhD of the first author and was presented in an earlier form at the 50th European Regional Science Association Annual Congress, Jönkoping, 2010. We would like to thank two anonymous reviewers and the special issue editor, Karst Geurs, for helpful feedback which has improved this paper.

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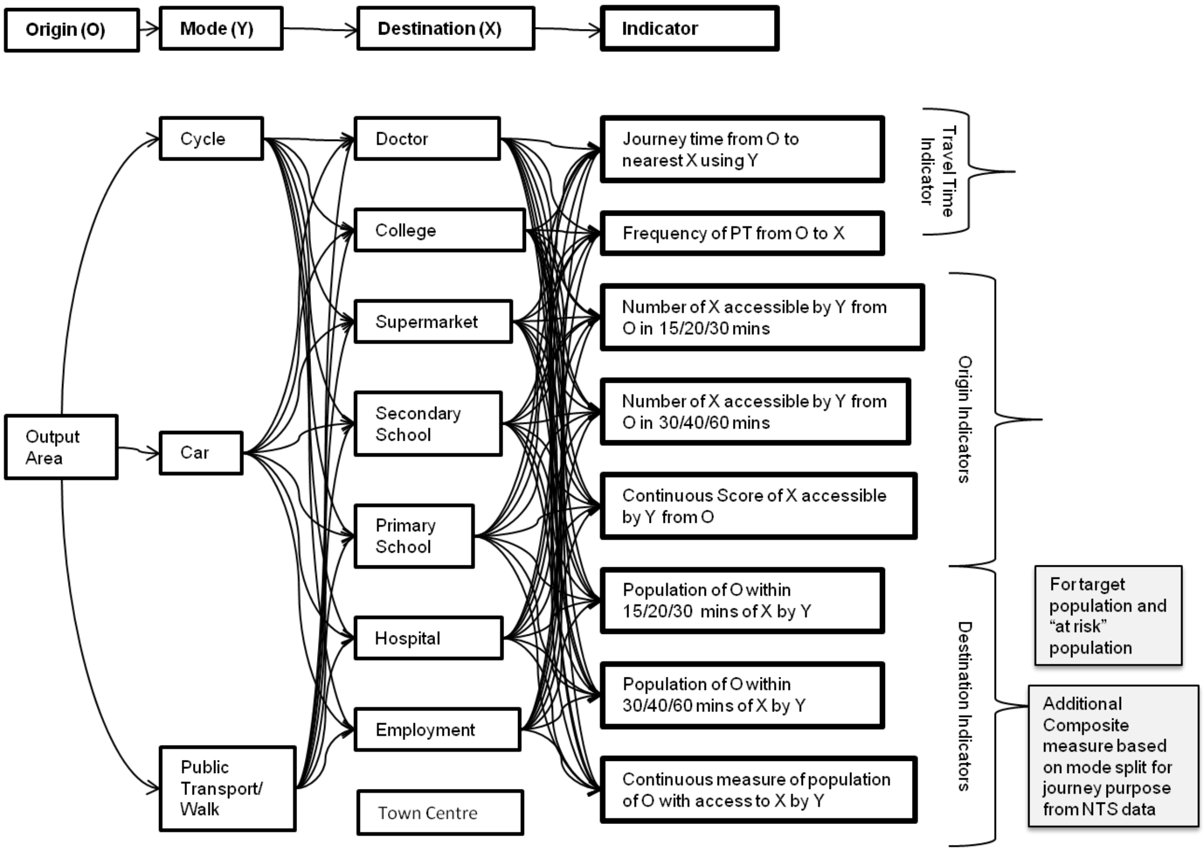
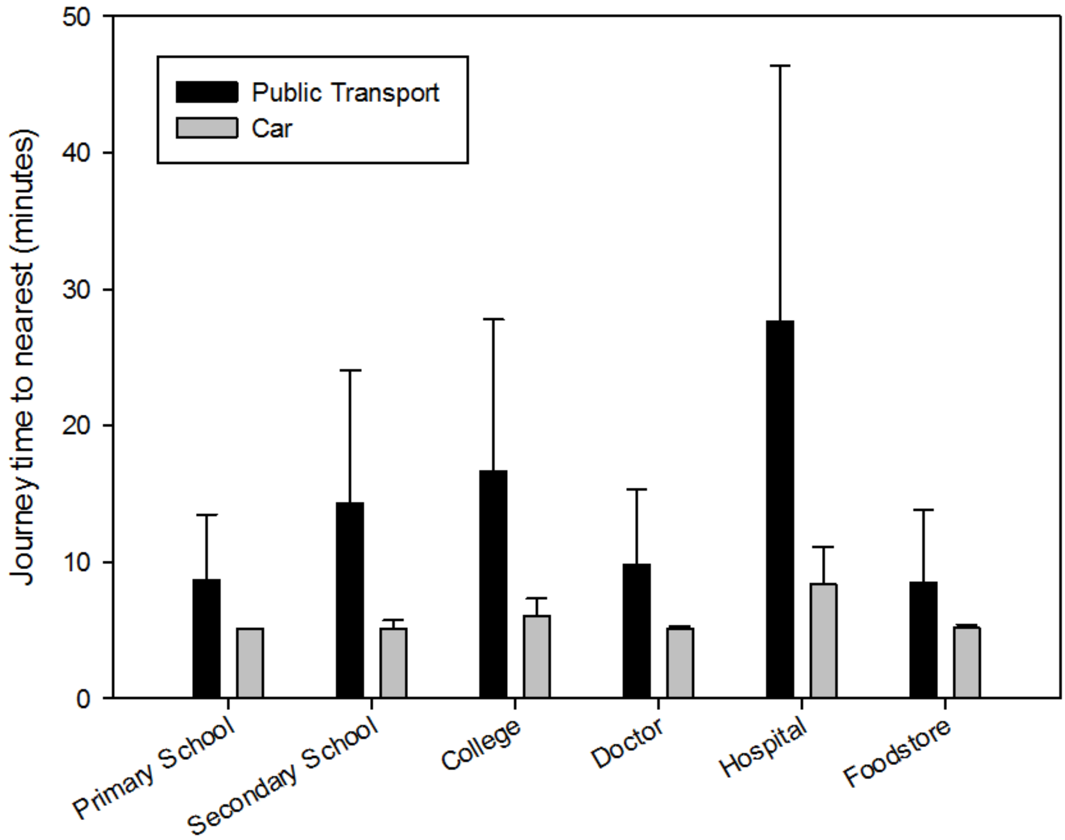
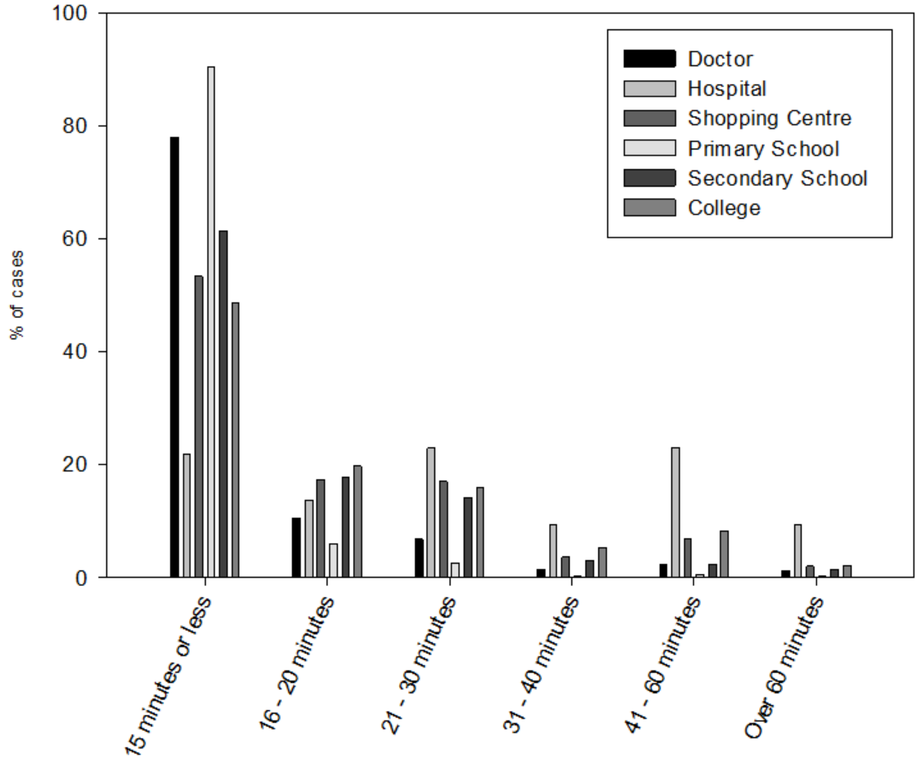

Origin (O)
Mode (Y)
Destination (X)
Indicator
Output Area
Cycle
Car
Public Transport/ Walk
Doctor
College
Supermarket
Secondary School
Primary School
Hospital
Employment
Town Centre
Journey time from O to nearest X using Y
Frequency of PT from O to X
Number of X accessible by Y from O in 15/20/30 mins
Number of X accessible by Y from O in 30/40/60 mins
Continuous Score of X accessible by Y from O
Population of O within 15/20/30 mins of X by Y
Population of O within 30/40/60 mins of X by Y
Continuous measure of population of O with access to X by Y
Travel Time Indicator
Origin Indicators
Destination Indicators
For target population and "at risk" population
Additional Composite measure based on mode split for journey purpose from NTS data

Figure 1



Journey time to nearest (minutes)
0
10
20
30
40
50
Public Transport
Car
Primary School
Secondary School
College
Doctor
Hospital
Foodstore

Figure 2



100
80
60
40
20
0
% of cases
Doctor
Hospital
Shopping Centre
Primary School
Secondary School
College
15 minutes or less
16 - 20 minutes
21 - 30 minutes
31 - 40 minutes
41 - 60 minutes
Over 60 minutes

Figure 3

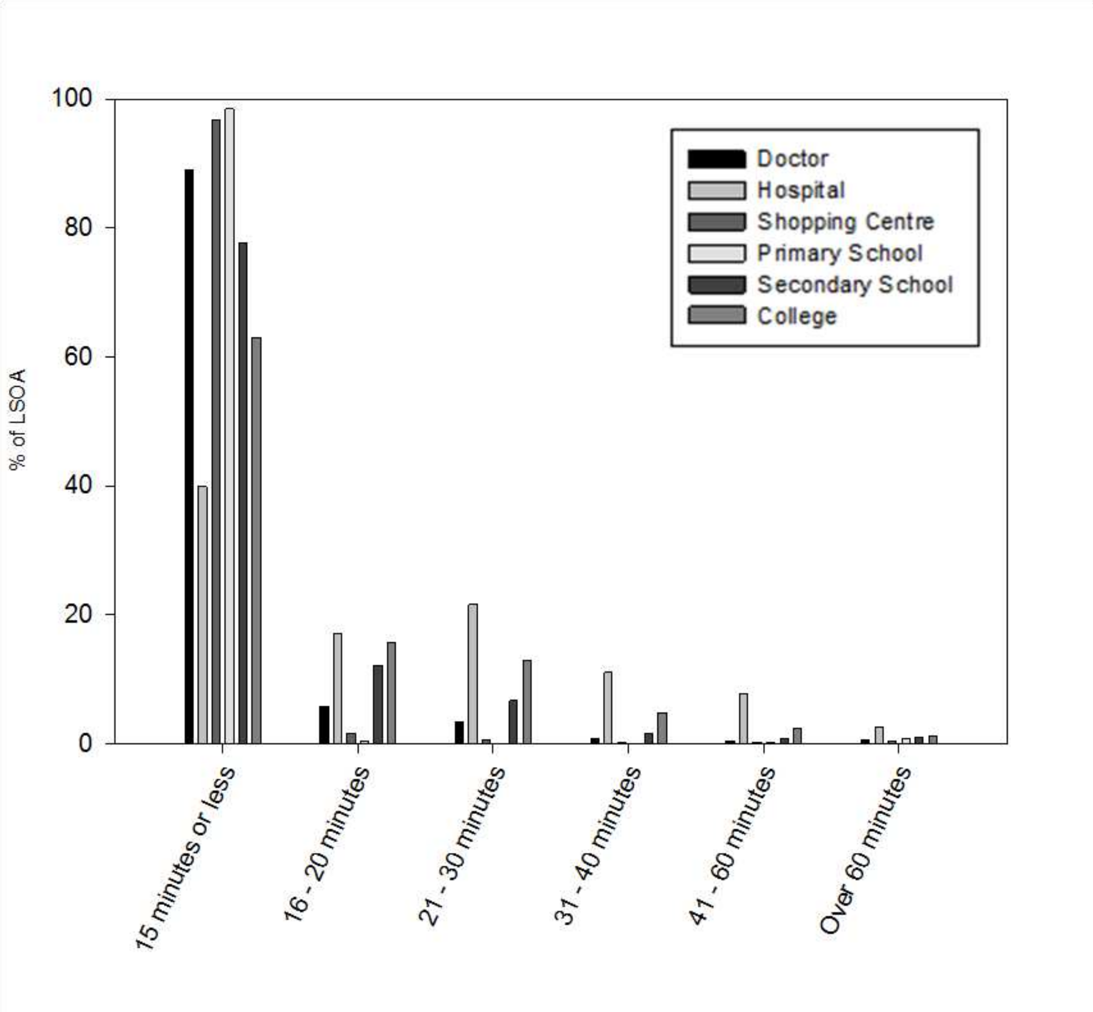

100
80
60
40
20
0
% of LSOA
Doctor
Hospital
Shopping Centre
Primary School
Secondary School
College
15 minutes or less
16 - 20 minutes
21 - 30 minutes
31 - 40 minutes
41 - 60 minutes
Over 60 minutes

Figure 4

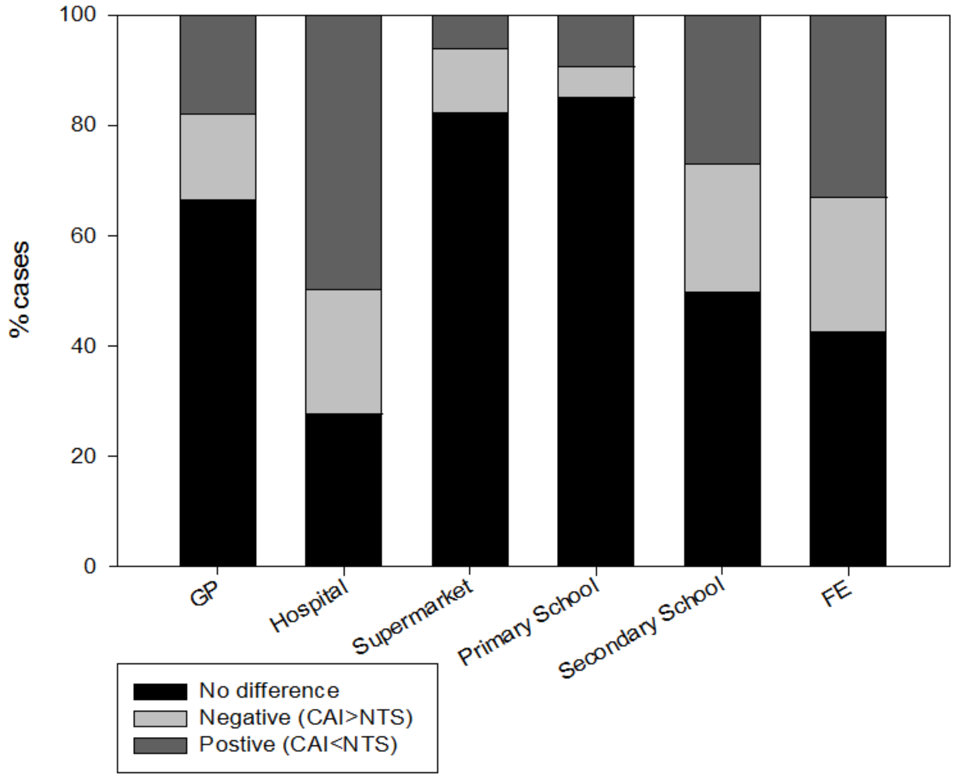

% cases
0
20
40
60
80
100
GP
Hospital
Supermarket
Primary School
Secondary School
FE
No difference
Negative (CAI>NTS)
Postive (CAI<NTS)

Figure 5

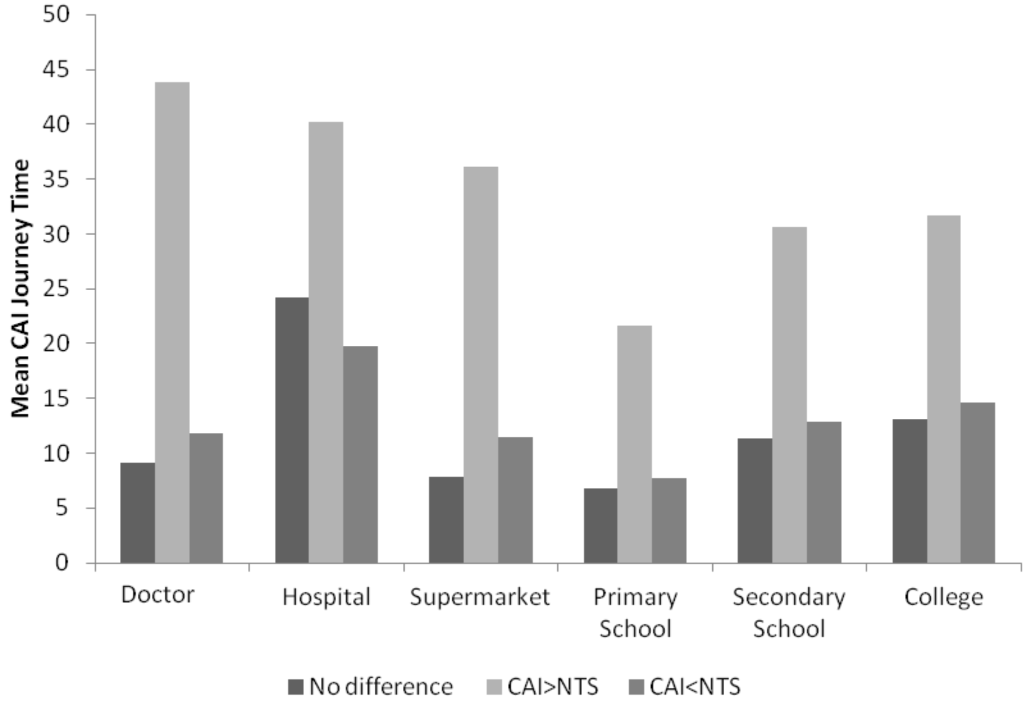

Mean CAI Journey Time
50
45
40
35
30
25
20
15
10
5
0
Doctor
Hospital
Supermarket
Primary School
Secondary School
College
No difference
CAI>NTS
CAI<NTS

Figure 6

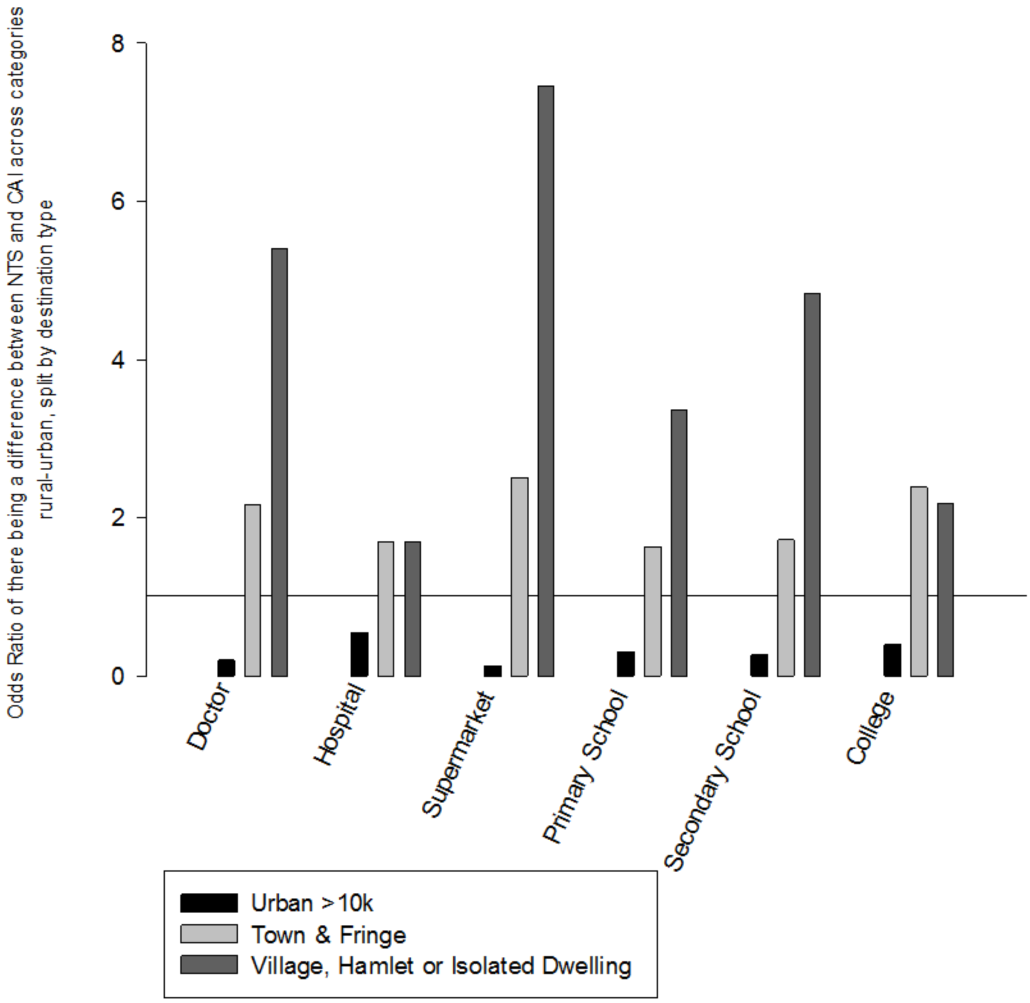

Odds Ratio of there being a difference between NTS and CAI across categories rural-urban, split by destination type
8
6
4
2
0
Doctor
Hospital
Supermarket
Primary School
Secondary School
College
Urban >10k
Town & Fringe
Village, Hamlet or Isolated Dwelling

Figure 7

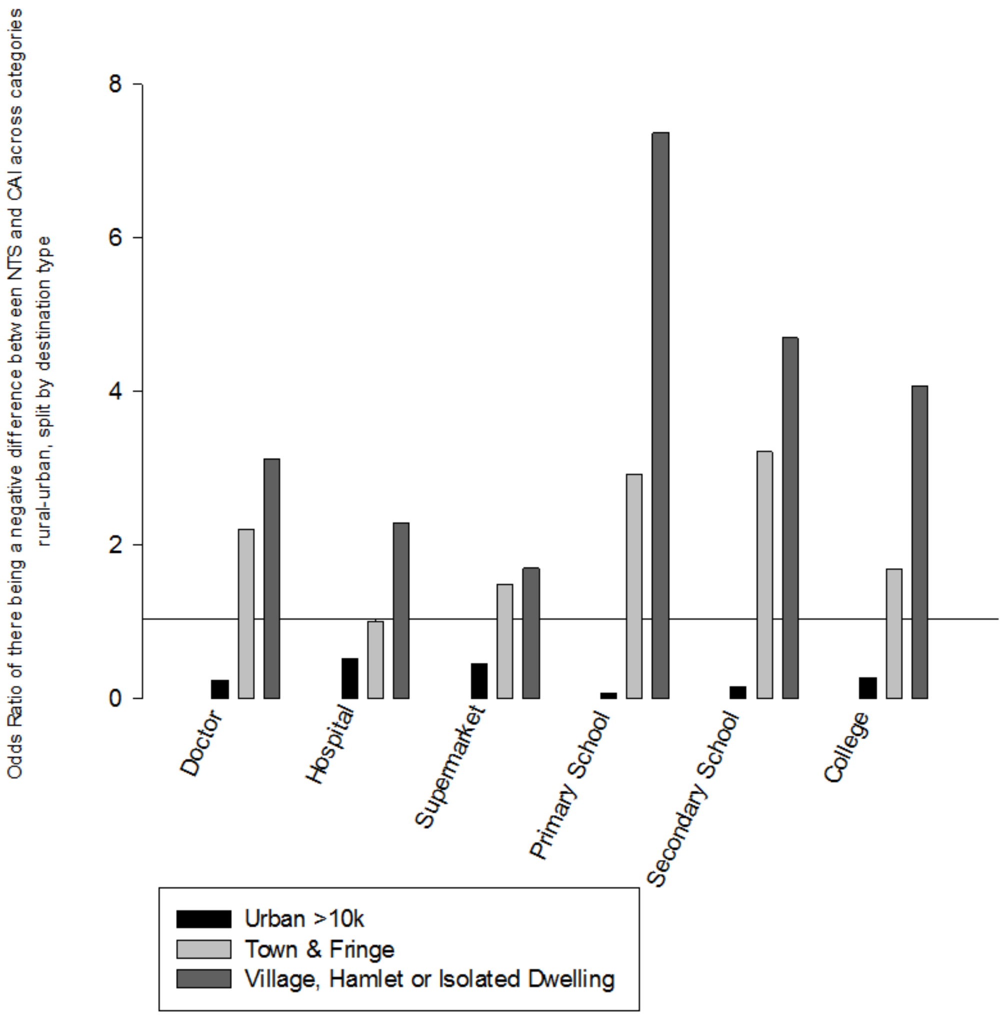

Odds Ratio of there being a negative difference between NTS and CAI across categories rural-urban, split by destination type
0
2
4
6
8
Doctor
Hospital
Supermarket
Primary School
Secondary School
College
Urban >10k
Town & Fringe
Village, Hamlet or Isolated Dwelling

Figure 8