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Using floating catchment analysis (FCA) techniques to examine intra-urban variations in accessibility to public transport opportunities: the example of Cardiff, Wales

M. Langford [a], G. Higgs [a,*], R. Fry [b]

[a] GIS Research Centre and Wales Institute of Social and Economic Research, Data and Methods, Faculty of Advanced Technology, University of Glamorgan, Pontypridd, Wales CF37 1DL, UK
[b] Centre for Health Information, Research and Evaluation (CHIRAL), College of Medicine, Floor 3, Institute of Life Science 2 (ILS2), Swansea University, Singleton Park, Swansea SA2 8PP, UK

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ABSTRACT

A relatively large literature base exists on the use of GIS to measure accessibility in transport studies. Often such research efforts have been conducted as part of wider studies of social exclusion to public transport opportunities. This paper aims to explore the use of floating catchment analysis (FCA) techniques to measure access to public transport opportunities. Whilst FCA methods have been used to measure access to health, employment and leisure services in particular, there have been few studies focused on their potential for measuring access to public transport services. This study builds on previous research concerned with enhancing the FCA methodology to include aspects of proximity to bus stops, the balance between service supply and demand, and cumulative opportunity. We compare FCA-based access measures with both census-derived data and small area geodemographic classifications in order to explore intra-urban variations in accessibility and potential associations with existing socio-economic patterns. Our findings for the city of Cardiff, UK highlight no strong associations with potential measures of social exclusion, and points to evidence that deprived areas within the city are actually better served in terms of the provision of public transport opportunities than some affluent areas. These findings contrast with previous studies which have found disparities between transport supply and social needs. We suggest enhanced FCA measures have real potential in studies of transport-related social exclusion in identifying locations where services should be provided in relation to potential demand as well as in monitoring the implications of placing new routes and access points.

1. Introduction

A report by the Scottish Executive suggests that "transport-related social exclusion occurs where individuals or households are unable to fully participate in society as a result of inadequate or unaffordable transport" (Stradling et al., 2005, p. 5). Previous studies have highlighted the link between various dimensions of social exclusion and a range of transport indicators, and the potential implications of variations in access to transport services for disadvantaged communities (e.g. Church et al., 2000; Hine and Mitchell, 2003; Lucas, 2004; Currie, 2011). Several UK Government policy reports over the last decade have highlighted the importance of accessibility of public transport (e.g. Department of the Environment, Transport and the Regions, 2000; Social Exclusion Unit, 2003) and a recent House of Commons Transport Select Committee report (2011) drew attention to the likely disproportionate impacts of cuts to public transport provision for some of the most "vulnerable people in society". Others have explored the impacts (both direct and indirect) of socio-economic factors on the provision of bus services at a neighbourhood level (e.g. the study by Wells and Thill (2012) of provision within four US cities in relation to the so-called "underclass hypothesis"). Geographical Information Systems (GIS) have been used extensively to develop sophisticated accessibility measures as part of wider studies of social exclusion and transport disadvantage (Currie, 2004; Dodson et al., 2006; Halden, 2002; Martin et al., 2008; Vandenbulcke et al., 2009). In the light of research which suggests that spatial access to services can be problematic especially for those most likely to depend on public transport (such as elderly groups, those with long term health problems, the young, or lower income households) in this paper we are concerned with applying innovative GIS-based techniques in order to examine spatial variations in access to bus services. Whilst acknowledging the importance of overall journey times through the network, the main research question posed here

* Corresponding author.
E-mail address: ghiggs@glam.ac.uk (G. Higgs).

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concerns a comparison of the distribution of access to transport opportunities in relation to spatial patterns of social disadvantage and geodemographic area classifications, both based on UK 2001 Census data, across the city of Cardiff, Wales.

In a previous paper we outlined methodological enhancements to an existing accessibility measure, the 'floating catchment area' technique (Langford et al., 2012). Using publicly available transport timetable information for a unitary authority in South Wales we demonstrated how more nuanced disaggregate analysis of variations in accessibility can be derived using these new methodologies. As part of the conclusions to that study we suggested follow-up research should involve an examination of how patterns of potential accessibility compare to various aspects of socio-economic status of spatial areas in wider studies of potential transport disadvantage and social exclusion. In this paper, using the city of Cardiff as an example, we apply these methods to explore for the first time intra-urban variations in accessibility to public transport opportunities using enhanced floating catchment area techniques. Delbosc and Currie (2011) amongst others have recently identified those social groups most likely to be impacted by transport disadvantage and social exclusion and we have drawn on such literature to compare our calculated access scores for small areas with census-derived socio-economic variables for our study area.

The rest of this paper is structured as follows: First we provide a brief background to the use of access-based measures in transport-related social exclusion before describing relatively new GIS-based techniques which can simultaneously account for public transport supply measures as well as population demand to provide a more realistic appraisal of accessibility. These techniques are illustrated with reference to a case study of access to bus services in the city of Cardiff. The methodology is presented in Section 3 of the paper and our preliminary findings of the relationship between resultant access scores and socio-economic indicators at the intra-urban levels are described in Section 4. Section 5 discusses the implications of these findings, summarises the advantages of using enhanced floating catchment area techniques to capture information relating to access to public transport opportunities, and suggests areas for further research in relation to wider studies of transport disadvantage. The final section provides a summary of key findings and reiterates the importance of such techniques in researching transport related social exclusion.

2. Background

2.1. Accessibility, transport disadvantage and social exclusion

There has been a growing realisation of the potential links between aspects of transport disadvantage and dimensions of social disadvantage in the transport geography literature (Hine and Mitchell, 2001, 2003). The various policy documents alluded to previously, which acknowledged the importance of transport in influencing patterns of social exclusion, have led to renewed interest in developing measures which could be used in accessibility planning to address this agenda (Social Exclusion Unit, 2003). Such measures have been refined to represent social dimensions of travel and in particular to examine differential levels of access for different social groups. Such studies have included attempts to provide access to public transport opportunities using techniques such as buffer zones (Murray et al., 1998), isochrones (O'Sullivan et al., 2000), or gravity models. Kwan (1998) reviewed the respective strengths and limitations of different measures of individual accessibility (based on gravity type and cumulative opportunity measures) with time–space measures using network-based GIS and data derived from travel diaries. For example, using simple population-to-provider ratios as a measure of accessibility is problematic for small areas in particular, since there is likely to be movement of people across boundaries to access services in neighbouring areas. Others have explored the use of grid-based models of accessibility in studies of potential spatial associations of access scores with poverty indicators (Ahlstrom et al., 2011). The use of a variety of accessibility measures in transportation studies has more recently been reviewed by Paez et al. (2012).

Kamruzzaman and Hine (2011) describe a number of different measures of transport disadvantage which they group into *process* based and *outcome* based measures. The former include deprivation measures (based on distance to opportunities), area accessibility measures (based on the count of numbers and types of opportunities within specified travel distances) and area mobility measures. Outcome-based measures they posit can be derived from the activity spaces of individuals based on their actual travel behaviour which may be gauged from, for example, travel diaries. Area mobility measures have been commonly used to examine distances to public transport opportunities (e.g. bus stops) from within areas (commonly from a representative point – usually the centroid of a census unit). Whilst the disadvantages of area-based approaches for identifying variations in relation to social need are widely recognised from both conceptual and methodological standpoints, in the absence of more disaggregate demand and supply data they continue to be used albeit with a greater degree of refinement. Currie (2004, 2010), for example, used GIS-based techniques to identify 'gaps' in public transport provision in relation to socio-economic data from the census for the city of Melbourne. By examining the characteristics of people outside specified walking distances of service points Currie identified intra-urban variations in the relationships between transport supply and potential need across the city. An extension to such methodologies has been the inclusion of measures of transit frequency (defined as the average number of distinct public transport journeys through individual transit stops) in order to examine variations in access for Auckland, New Zealand (Mavoa et al., 2012). These were used to compute the percentage of population living in small areas (meshblocks) with varying levels of public transit accessibility although no attempt was made to examine such trends in relation to socio-economic characteristics of these areas.

Other studies derive accessibility measures based on public transport network models that take into account bus and rail routes/stops, transfers, walk access times and waiting times and have examined these in relation to areas of socially excluded groups, transport needs measures and access to 'key activities' (e.g. Church et al., 2000; Murray and Davis, 2001; Lei and Church, 2010). Wu and Hine (2003), for example, illustrate how GIS can be used to forecast the implications for accessibility levels caused by a hypothetical change in a public transport network. This was accomplished using changes in Public Transport Accessibility Levels (PTALs) indices prior to and following reconfiguration. Such indices are calculated using walk access times and service availability which Wu and Hine (2003, p. 309) argue is a methodology "particularly suited to local area studies in urban situations". Whilst PTAL does encompass a measure of the 'reliability' of the service, the number of services available and average waiting times at bus stops, the relationship between numbers of stops and potential demand points for these services is not explicitly accounted for. In addition, relatively few studies have explored how PTAL-revealed levels of access to public transport services relate to other aspects of social disadvantage. In the next section we outline how new measures based on 'floating catchment area' techniques can be used to redress such gaps in the literature.

2.2. Measuring access and enhanced 'floating catchment area' (FCA) techniques

Measures based on spatial proximity generally assume people use their *nearest* facility to access a particular service. This