Applied Geography 95 (2018) 19–33

Contents lists available at ScienceDirect

Applied Geography

journal homepage: www.elsevier.com/locate/apgeog

An evaluation of alternative measures of accessibility for investigating potential 'deprivation amplification' in service provision

Nicholas Page*, Mitchel Langford, Gary Higgs

Wales Institute of Social and Economic Research, Data and Methods (WISERD) and GIS Research Centre, Faculty of Computing, Engineering and Science, University of South Wales, Pontypridd, CF37 IDL, United Kingdom

ARTICLE INFO

Keywords:
Service provision
Socio-economic patterns
Accessibility measures
Two-step floating catchment area (2SFCA) methods
Sensitivity analysis

ABSTRACT

Studies examining potential social inequities in resource distribution have tended to adopt relatively unsophisticated measures of service supply such as those derived from proximity measures or counts of facilities within given time/distance thresholds. Often such measures do not take into account potential demand for services and the implications this has for understanding socio-spatial patterns in service provision. In this paper, a comparison is made between spatial patterns of accessibility to a range of services by socio-economic gradients for a subset of 'traditional' measures of provision with trends revealed by the use of floating catchment area (FCA) methods. Statistical and visualisation tools are employed to examine variations in access scores across deprivation quintiles for all the services included in an accessibility 'domain' of a policy-relevant Index of Multiple Deprivation. Findings suggest that, whilst the use of proximity or cumulative opportunity approaches consistently point to greater levels of access in more deprived areas, results from the application of FCA methods point to non-linear trends in the relationship between access and socio-economic patterns of deprivation for some key services. This suggests that the use of measures that account for both potential service demand and distance-decay effects demonstrate patterns that are at odds with those revealed by the use of 'traditional' metrics. We conclude by highlighting prospective implications of using different methodological approaches to measuring spatial patterns of accessibility for understanding socio-economic patterns in service provision, and the broader policy relevance of encapsulating potential service demand within socio-spatial investigations of levels of access.

1. Introduction

Spatial accessibility is one of a number of recognised barriers to wider considerations of access; the others being availability, affordability, acceptability and accommodation (Penchansky & Thomas, 1981). It refers to a consideration of both the availability of a service (e.g. the number of available supply points) and the geographical distances involved in accessing a service (often measured by the travel cost between the service delivery point and potential users; Guagliardo, 2004). From a policy perspective, the measurement of 'potential' spatial accessibility (hereafter 'accessibility'), which refers to prospective levels of accessibility based on the analysis of spatial patterns in physical access to services (rather than actual patterns in service utilization; so called 'realized' accessibility), can inform policymakers of potential disparities in provision by identifying areas where levels of accessibility are poor and targeted interventions needed (Joseph & Phillips, 1984). Such an approach is particularly common in the context of healthcare where, for example, levels of accessibility to primary care physicians have been estimated to highlight potential inequalities in healthcare delivery (Luo, 2004). An important area of study, inequitable levels of access can have important effects on health outcomes – for example, lower levels of access to cancer screening facilities has been associated with an increased risk of late-stage cancer (Wang, Luo, & McLafferty, 2010).

Over the last decade there has been a proliferation of Geographic Information System (GIS)-based studies that have investigated spatial patterns in service accessibility across various geographical and socio-spatial contexts (e.g. Bauer, Müller, Dörthe, & Groneberg, 2017; Macintyre, Macdonald, & Ellaway, 2008; Pearce, Witten, Hiscock, & Blakely, 2007; Pearce, Witten, Hiscock, & Blakely, 2008). Many such studies examine accessibility to health promoting (or so-called 'salutogenic') services, such as sports facilities (e.g. Billaudeau et al., 2011; Ferguson, Lamb, Wang, Ogilvie, & Ellaway, 2013; Higgs, Langford, & Norman, 2015; Lamb, Ferguson, Wang, Ogilvie, & Ellaway, 2010; Lamb et al., 2012; Ogilvie, Lamb, Ferguson, & Ellaway, 2011), green spaces (Higgs, Fry, & Langford, 2012) or healthy food opportunities (Smith

* Corresponding author. University of South Wales, Faculty of Computing, Engineering and Science, Room J313, United Kingdom.
E-mail address: nicholas.page@southwales.ac.uk (N. Page).

https://doi.org/10.1016/j.apgeog.2018.04.003
Received 14 December 2017; Received in revised form 27 March 2018; Accepted 4 April 2018

et al., 2010), as part of wider studies that explore the interaction between compositional (people) and contextual (place) factors and their impact on health outcomes (Macintyre, Maciver, & Soomans, 1993). 'Deprivation amplification' is a hypothesis which proposes that "… poorer neighbourhoods will usually have poorer access to health promoting resources and more exposure to health damaging ones …" (Macintyre et al., 2008, p. 901), and has tended to form the conceptual basis of these and similar investigations. To date, however, there has been mixed support for the 'deprivation amplification' hypothesis with some findings suggesting a less uniform association between patterns of service accessibility and levels of area deprivation. This has led to refinements of the concept to suggest that "[t]he spatial distribution of resources by deprivation may vary between types of resource, geographical location …, countries, and time periods" (Macintyre, 2007, p. 902). In this paper, we posit that a further component, namely the methodological approach used to measure accessibility, may also impact on such trends and can be expected to influence investigations into potential deprivation amplification in resource access.

Studies examining associations between levels of service accessibility and indicators of area level deprivation have tended to rely on relatively simplistic approaches to measurement, such as population-provider ratios (PPRs; Cummins, McKay, & Macintyre, 2005), average or median distances (Pearce et al., 2008; Smith et al., 2010), shortest distance to nearest service (Macintyre et al., 2008), or number of facilities available within a specified time/distance threshold (Ferguson et al., 2013; Lamb et al., 2012; Ogilvie et al., 2011). Whilst each of these approaches has their respective strengths, a major contention of this paper is that most fail to consider important interactions between supply and potential demand, which could have wider implications for studies of socio-economic disparities in provision. In particular, we argue that it makes more sense when investigating levels of service accessibility to measure both supply and demand and their interactions in instances where, for example, good geographical access to services may be undermined by high levels of demand in the immediate vicinity of services, or vice versa. In this context, approaches to accessibility measurement that neglect potential demand will only provide partial insights into spatial patterns of levels of access.

The purpose of this paper is to examine the degree to which associations between levels of access and socio-economic deprivation are dependent on the methodological approach to accessibility measurement. This is achieved through a comparison of trends revealed using traditional approaches to accessibility measurement (PPR, minimum travel time, and cumulative opportunity) with levels of access calculated using floating catchment area (FCA) methods. Research intent on directing policy must be based on the most up-to-date techniques. In the context of measuring access, FCA-based measures are assumed to be more spatially advanced than 'traditional' methods because they potentially enable more nuanced patterns of access to be obtained that account for the interactive effects of supply capacity, demand volume, and travel distance/time. In this paper, we aim to build upon previous studies which have examined implications arising from different approaches to measuring accessibility (e.g. Apparicio et al., 2017; Dewulf, Neutens, De Weerdt, & Van de Weghe, 2013; Neutens, 2015) by considering these effects at national level, for multiple services, and in terms of associations with socio-economic variations in deprivation.

2. Approaches to measuring spatial accessibility

2.1. 'Traditional' approaches

Many methodological approaches have been used in a GIS environment to estimate potential levels of service accessibility (for reviews, see Neutens, 2015; Wang, 2012; Higgs, 2004; Yang, Goerge, & Mullner, 2006; Paez, Scott, & Morency, 2012). Container and distance-based measures are the 'traditional' approaches to measuring potential accessibility. The former is based on simple supply-to-demand ratios (or 'PPRs') computed inside areal boundaries such as administrative units; the latter measure a time or distance to reach a service from a specified point of origin (the 'demand centre'). The application of a container-based approach, for example, could include calculating the ratio of primary healthcare physicians within a given area relative to the number of potential patients, whilst a distance-based approach might compute the shortest distance from the population-weighted centroid of a census tract (or similar) to the nearest available physician (Dewulf et al., 2013). In the absence of more detailed data on residential location, demand centres are commonly representative of the centroid of a spatial unit; a point which can be population-weighted and/or further refined through land use maps (Apparicio et al., 2017).

A strength of these measures is that they are easily computable with basic GIS capabilities and are also straightforward to interpret as they are based on absolute units (Neutens, 2015). However, both have limitations that, arguably, make them less appropriate for measuring accessibility at detailed geographical scales. For instance, container methods neglect possible cross-border flows, assuming that users always remain inside their respective boundaries and do not, regardless of geographical proximity, access services in neighbouring areas. This approach also assumes equal access across the entirety of the container regardless of actual proximity (Luo & Qi, 2009). In a similar vein, distance methods using Euclidean (straight-line) or Manhattan measures do not reflect 'real-life' travel based on actual road networks, with speed limits and other relevant travel impedances. Whilst advancements in GIS routing algorithms coupled with increased availability of detailed transport data have ameliorated such criticisms, these metrics still fail to consider any implications arising from local demand levels, and neglect the individual agency of service users by assuming that travel distance/time is the only relevant factor mitigating service choice, rather than, say, service quality or personal preference.

To lessen the deficiencies of both methods, by utilising the evolving functionality of a GIS, some studies have used a combination of both container and distance approaches. They adjudge a 'cumulative opportunity' for accessing a service by placing a buffer around each demand centre and summing the number of supply points within this catchment. Such buffers can be based on circles of different radii or use varying network travel times/distances. For example, Ferguson et al. (2013) examined accessibility to physical activity facilities by car and bus using cumulative opportunity recorded in 10, 20 and 30-min travel time buffers based on a network model of mainland Scotland. Dewulf et al. (2013) used a similar approach in their analysis of primary care accessibility in Belgium, albeit applying distance buffers of 5 km and 10 km respectively. The main advantage here is that the movement of service users is not unrealistically constrained by abstract areal boundaries, and nor is accessibility measured solely by the closeness of a single service supply point. However, these strengths are tempered by a failure to address potential demand implications in the cumulative opportunity calculation.

2.2. Floating catchment area (FCA) techniques

A derivative of the geographical gravity model, FCA spatial accessibility models can be considered an enhancement on the traditional metrics previously discussed, primarily because they incorporate elements of both supply-to-demand ratio, cumulative opportunity and travel cost in their outputs (Luo & Wang, 2003). In the two-step FCA (2SFCA) specification, a maximum travel threshold is set (using either time or distance) which then determines a catchment area around each service supply point – for example, a 500 m travel radius around each sports facility site (Higgs et al., 2015). A supply-to-demand ratio is then determined from the available supply capacity at this point relative to the number of potential users that fall inside its catchment. In step two, a catchment of equal distance (or time) is placed around each demand centre. A final 2SFCA score is recorded as the sum of the supply-to-demand ratios of all service provision points that fall inside this