

The application of network-based GIS tools to investigate spatial variations in the provision of sporting facilities

Mitchel Langford¹, Gary Higgs^{1*}, and Jonathan Radcliffe²

1. GIS Research Centre, Wales Institute of Social and Economic Research, Data and Methods (WISERD), Faculty of Computing, Engineering and Science, University of South Wales, Pontypridd, UK CF37 1DL

2. Sport Wales, Sophia Gardens, Cardiff, CF11 9SW

* Corresponding author (gary.higgs@southwales.ac.uk)

Abstract

Methods whereby access to facilities can be captured in order to support national policies geared towards promoting sports participation and help plan the provision of local facilities are urgently needed. Objective measures derived from the use of Geographical Information Systems (GIS) can be used to gain an understanding of spatial variations in the location and quality of sporting infrastructure. The aim of this study is to draw on a recreational database for Wales to demonstrate the benefits of ‘enhanced two-step floating catchment area’ (E2SFCA) techniques for gaining a wider understanding of variations in potential demand for sport facilities in the light of available supply. A practical demonstration showing how such tools can be used to examine variations in provision in relation to potential demand arising from targeted demographic groups is illustrated using the case study of spatial access to lawn bowling greens, an increasingly popular leisure pursuit in Wales.

Keywords: Sporting infrastructure; Accessibility; Geographical Information Systems (GIS); Enhanced Two-Step Floating Catchment Area (E2SFCA) models; Leisure facilities

1. Introduction

Previous studies have highlighted the need to investigate geographical accessibility of recreational facilities as a potential contributory factor when analysing socio-economic variations in sports participation and its potential impact on levels of physical activity (Humpel et al., 2002; Diez Roux et al., 2007; Kaczynski and Henderson, 2007; Powell et al., 2007; Wendel-Vos et al., 2007; Sterdt et al., 2014). Qualitative studies have found that proximity to facilities, or the level of provision of recreational facilities within local neighbourhoods, can influence physical activity behaviour (Persson and While, 2011), with some evidence that the range of activities on offer also impact on levels of use (Kirby et al., 2013). Whilst there is widespread recognition that age, gender, culture, ethnicity, transport availability and socio-economic circumstances all play a role in influencing levels of physical activity within communities (see Limstrand, 2008, for a wider review) there remains within the health and sport geography literature a continuing interest in the specific impact of spatial accessibility to sporting infrastructure. Findings are contradictory, with some studies suggesting no relationship between the spatial availability of sports facilities and sports participation or physical activity levels (Diez-Roux et al., 2007; Pascual et al., 2009; Prins et al., 2009), while other studies report that relationships between accessibility and the use of sports facilities may hold for certain sporting facilities but not for others (Billaudeau et al., 2011). For example, from a study conducted in the Paris metropolitan area, Karusisi et al. (2013; p. 9) conclude that "...disparities in the spatial accessibility to sport facilities do not have a major impact on utilization, except perhaps for swimming pools".

The advantages of using Geographical Information Systems (GIS) to understand how spatial access to facilities may be associated with variations in socio-demographic characteristics of areas by enabling the provision of physical activity infrastructure to be captured have been highlighted in previous studies (Estabrooks et al, 2003; Macintyre, 2007; Moore et al., 2008;

Prins et al., 2012). However, the methodology used to measure and define the local neighbourhood often varies, and this may influence the levels of association found between the extent of provision and participation in sporting activities (see Brownson et al., 2009 for a wider review). This suggests that more attention should be given to investigating the likelihood that different sports facility types are used by different demographic user groups, and that tailoring GIS-based techniques to explore the impacts of varying levels of demand whilst also accounting for underlying population characteristics could prove a fruitful area for further research. Findings published to date tend to have been based on trends observed in relatively small study areas (e.g. using a city boundary as the base unit of analysis) with relatively few studies adopting an approach that enables their outcomes to be transferred to alternative contexts (Powell et al., 2006; Hillsdon et al., 2007). Finally, and of immediate relevance to the aims of this study, analyses have often relied on simplistic indices of access derived from the absence/presence of facilities within the boundaries of administrative units, or the ratio of service supply to population counts computed within such units. This has led others to promote alternative methods that might better account for the inevitable ‘cross-border flows’ of those people accessing facilities further afield (Luo and Wang, 2003). Such techniques include the use of distance-based metrics, kernel density estimation (Jones et al., 2015), and floating catchment area (FCA) techniques (Cutumisu and Spence, 2012); the latter of which are the focus of this study.

Several recent studies investigating patterns in sport participation have recognised the limitations of subjective interpretations of sports provision and have advocated the adoption of more rigorous objective measures of supply-side characteristics using geospatial techniques (e.g. Hallmann et al., 2012; O’Reilly et al., 2015). This study contributes to such aims by describing the development of customised GIS tools that allow accessibility scores to different types of sporting facility to be readily computed and then mapped to explore

evidence of spatial patterns. An add-in tool (equivalent to the ‘plugin’ in other software packages) has been developed for a popular GIS package and made freely available by the researchers to permit application in other contexts. Written in VB.NET it exploits the ArcObjects development environment, which provides programmatic access to all ArcGIS capabilities, and presents to the user a simple customised interface allowing E2SFCA modelling parameters to be specified. It then leverages the Network Analyst extension to compute an Origin-Destination matrix reporting computed network distance between all supply and demand locations, which is passed through bespoke algorithms to derive a range of quantitative accessibility metrics. The add-in consists of a single compressed file which is installed simply by placing it into a user-specified folder location.

The add-in enables databases routinely collected by organisations for tasks such as basic mapping, decision-support related to the allocation of funding, and interactive map-based searches by the general public, to be leveraged into providing further analysis and better insight into existing levels of facility provision. To illustrate its application in the context of an organisation charged with promoting and encouraging sports participation, we describe its adoption by the “Sport Wales” organisation. This tool allows its researchers to utilise a recreational database of facilities for Wales, together with open source data relating to UK socio-economic characteristics and the road network, to examine spatial variations in potential accessibility at a range of spatial scales. Similar databases encompassing different aspects of sport provision are now routinely collated by private and public sector organisations in many countries, often as part of their operational and strategic decision-making processes. Thus the tool can be applied in contexts beyond the UK by using, for example, crowd-sourced road network data such as OpenStreetMap and other sources of openly available spatial data. The longer-term goal of this research is to draw upon such tools to facilitate an investigation into the implications of using alternative approaches to defining

neighbourhood environments whilst examining potential levels of association between sports provision and socio-economic indicators.

The add-in tool also permits the user to readily incorporate any empirical evidence that may have been collected on the actual usage of sports facilities; for example, regarding the distances different socio-demographic groups are prepared to travel in order to access facilities, or their preferred modes of travel. Thus a key advantage of such tools is the flexibility they afford to non-GIS specialists to conduct sensitivity analysis by varying modelling parameters in the case of data being made available from in-house surveys of participants accessing different types of sporting activities. The primary contribution of this study is to illustrate the practical relevance of bespoke GIS tools in gaining a wider understanding of variations in potential demand for sport facilities in the light of available supply. To illustrate the advantages of sophisticated FCA-based measures for examining spatial variation in sport provision, a detailed worked example is provided that explores access to an increasingly popular sporting activity in Wales (lawn green bowling).

The rest of this paper is structured as follows; firstly the limitations of 'traditional' techniques for calculating accessibility are highlighted and a brief introduction given to FCA approaches. The aim is to describe conceptually how FCA scores are derived before presenting the add-in which allows such measures to be easily computed. Then, by drawing on our empirical study, we illustrate how an investigation of spatial patterns of accessibility to one type of leisure facility, that accounts for both the availability and potential demand for that activity, could be adopted as part of a much wider approach geared to understanding the factors impacting on variations in sports participation. Finally, in our conclusion we highlight areas for further investigation such as addressing some of the assumptions inherent in existing FCA approaches before re-iterating the policy importance of such research in

relation to recent initiatives aimed at increasing levels of sporting participation for a wide range of demographic groups.

2. Measuring access to sport facilities using Floating Catchment Area scores

2.1 'Traditional' approaches to measuring spatial variation in accessibility

Conceptual and methodological issues related to measuring potential spatial accessibility to different types of facilities/services have been reviewed by researchers such as Neutens (2015), Paez et al. (2012), Wang (2012) and Yang et al. (2006). Amongst the approaches used in those studies that aim to provide a better understanding of the impacts of variations in provision on, for example, variations in sport participation rates or levels of physical activity, two techniques are particularly well established. First, there are those that report the relationship between service supply and population demand using fixed spatial units, usually administrative areas (for example, the number of sports facilities relative to the total population count inside a census tract). It is quite straightforward for a GIS to compute the number of facilities found inside any administrative zone of choice and to compare this to a population total to calculate supply/demand ratios; this is often called the *container* approach. Another commonly adopted method is to measure the distance travelled, or time taken, to reach the closest sports facility, or the average of the same measure computed to all facilities that fall within a threshold distance. This metric can be modelled for individuals, but more commonly makes use of proxy locations for aggregated demand populations. Again it is a simple task for a GIS to compute straight-line distances between supply and demand points, or given suitable data, a more sophisticated network distance or even travel time.

Container based ratio scores are popular for evaluating spatial accessibility to a range of public and private services. Undoubtedly this is because they are easy to understand, easy to compute, and require data inputs that are typically readily available. Such ratios may be

adequate for certain policy scenarios or where funding is restricted to one administration area with little consideration for wider use amongst those living in neighbouring areas. However, the container approach suffers from well-documented limitations arising from its underlying assumption that residents only use facilities located within their administrative zone, and that access to services from inside the zone is spatially uniform. The containers effectively ‘hide’ any internal differentiation in accessibility, and although this problem may be countered by resorting to the use of ever smaller spatial zones such an action simultaneously exacerbates another problem arising from the assumption of impermeable borders. By neglecting those residents that use sports facilities located in adjoining areas (which might have a wider range of services or be more conveniently located closer to a place of work for example) or those that travel in to use such facilities from neighbouring administrative areas, it is highly likely that inappropriate accessibility scores will be assigned to areas and that spatial variations in accessibility within the selected area will remain ‘hidden’ (Talen and Anselin, 1998).

Problems with the container approach, together with the increasing availability of GIS software within organisations, have led to alternative measures of accessibility based on distance and time being routinely adopted by researchers interested in understanding the impact of spatial factors on participation rates (Brownson et al, 2009). Actual implementation may involve computing a basic ‘straight-line distance between the location of a population group (typically a census tract centroid) and the nearest service provision point. Alternatively, more sophisticated techniques make use of topological networks to record travel time or the actual distance encountered whilst traversing roads and pathways. Compared to the container approach distance based metrics can provide a finer level of differentiation in terms of proximity, but are themselves based on assumptions such as people accessing their nearest facility, and they ignore a whole host of factors such as quality of venues and user preferences/awareness.

Another commonly adopted GIS analytical method involves calculating the total aggregated provision of service, or 'cumulative opportunity', found within a spatial buffer constructed using either straight-line or travel-network based distances. In a recent example, Adams et al (2015) used 1 km street network buffers built around the geocoded addresses of a sampled population to determine the characteristics of the immediate neighbourhood (including private recreational facility density) and associated these with levels of physical activity. An advantage of this approach is that it avoids the use of census tracts as the spatial unit of analysis and so overcomes the failure to account for movement across arbitrary administrative boundaries. Recent research by Kim and Nicholls (2016) concerned with measuring access to public beaches has emphasised the need to conduct sensitivity analysis on both the travel distances (ranging from one to twenty miles in their study) and access measures (minimum distance, travel cost and opportunities available within threshold distances) used to identify the proportion of residents with potential access to such facilities. Furthermore, Kim and Nicholls suggest the choice of distance parameters and accessibility measures adopted within such studies may be influenced by the type of facility, transport modes and mobility levels. Their findings mirror those of Talen and Anselin (1998), in the study of the distribution of playgrounds in Tulsa, that demonstrate that different spatial patterns are likely to result from the use of such measures and that this in turn can impact on the conclusions from studies of potential spatial (in)equity of provision. However, relatively few studies to date have incorporated a range of accessibility measures or have attempted to assess the importance of different distance thresholds.

Whilst potentially an improvement over container based methods the distance techniques typically do not account for the level of potential demand placed upon the service by considering the total population or some population subset that has a greater propensity to use the facility. So, for example, if a person lives very close to a swimming pool but this pool

happens to be the nearest facility for several thousand others living in its vicinity, accessibility levels may not be as good as the simple distance indicator suggests. This problem has led researchers to explore ‘gravity models’ (of which ‘floating catchment area’ is a specific form) because these account for population demand and service supply, and allow neighbouring areas to contribute to a zone’s measure of accessibility even if the zone itself contains no sports facilities.

2.2 Floating catchment area (FCA) techniques

Floating catchment area (FCA) methods combine elements of both the container and the distance approaches described above. They compute accessibility within a catchment area, but this catchment is defined by a threshold distance (or time) and it ‘floats’ from one population demand centre to another. An accessibility score is determined at each demand location using a supply/demand ratio constructed within the floating catchment area (Luo and Wang, 2003; Luo, 2004). Furthermore, the contribution to a cumulative accessibility score made by each facility inside the catchment is itself weighted by the total demand population that is able to access it. Briefly, an FCA score is computed using the following algorithm:

Step 1: The process begins by considering each service supply point; say, for example, each swimming pool site within a region of interest. A GIS is used to compute a distance/travel time *catchment* around each facility in turn. All demand locations (e.g. population weighted centroids) falling inside each catchment are used to compute a supply-to-demand ratio associated with that particular supply site; put simply, a measure of its availability is determined. This computation requires a user-defined threshold to be specified (ideally based on empirical evidence). This parameter defines the maximum distance (or time) that it is

believed people are prepared to travel in order to reach the service. For example, an analyst might decide 5 km or 15 minutes is the maximum distance/travel time people are prepared to travel in order to access a swimming pool.

Algebraically, this operation is expressed as:

$$R_j = \frac{S_j}{\sum_{k \in \{d_{kj} \leq d_{\max}\}} P_k}$$

Where S_j is the measure of service supply volume available at location j (e.g. the number of swimming pool lanes, the area of the pool, the maximum permissible number of simultaneous users, etc.). P_k is the population count at location k which lies in the computed catchment area of service supply point j . In other words, the distance d_{kj} between the service supply point (e.g. swimming pool) and population demand point (census tract centroid) is less than the user specified threshold distance d_{\max} . This calculation is repeated at each supply point (e.g. every swimming pool) to obtain the score R_j , which is a supply-to-demand ratio computed using the service area catchment as the container object.

Step 2: Attention now switches to each population demand site which is typically, although not necessarily, represented by a census tract centroid. The GIS computes a distance/travel time catchment around each demand location and all service supply points (e.g. swimming pools) that fall within the zone are identified. The step 1 supply-to-demand ratios (i.e. R_j) of these points are summed to yield the cumulative service assessibility score for that population group.

Algebraically, this operation is expressed as:

$$A_k = \sum_{j \in \{d_{kj} \leq d_{\max}\}} R_j = \sum_{j \in \{d_{kj} \leq d_{\max}\}} \frac{S_j}{\sum_{k \in \{d_{kj} \leq d_{\max}\}} P_k}$$

In both steps of the FCA algorithm catchment areas may be calculated using either simple straight-line distances (i.e. circular buffers) or more realistic network-based catchments using travel distances/drive times. It is important to note that a FCA score remains a familiar supply-to-demand ratio just like that provided by a traditional container approach. It represents the proportion of the total service provision (e.g. total number of swimming pools in the entire study region) that is shared amongst, or consumed by, each particular geographical subset of the population. It thus follows that if the FCA score attributed to each demand site is multiplied by its associated population count, the sum of these figures returns the total service supply volume. Thus, put simply, an FCA score is the relative share of the total service supply that a person in each population centre can reasonably access.

FCA methodology provides a supply-to-demand ratio based on realistic travel catchments rather than the methodologically crude count of facilities in an administrative area of residence. This suggests it could be more promising as a proxy for levels of supply of sporting infrastructure in analytical approaches concerned with establishing the importance of those factors associated with variations in participation levels (Hallmann et al., 2011). The problem of accounting for flows across arbitrary administrative boundaries has been acknowledged as a potential limitation in the approach taken in studies of intra-urban variations in sports participation that utilise aggregate measures of sporting infrastructure (Brownson et al., 2009). The approach taken in this study directly addresses three issues that have been highlighted in previous research as being worthy of further study. Firstly, FCA models add an extra dimension to such research by relaxing the constraint of arbitrary administrative boundaries and allowing interaction between supply and demand to be

computed within proximal neighbourhoods. Secondly, by using network distances as opposed to Euclidean measures, the impact of the routes people actually take to access facilities can be better accounted for; a factor likely to be even more important in rural areas. And finally, by considering the choice available to all potential users within a time/distance catchment while incorporating distance-decay effects and demand-weighted service provision levels, FCA models move well beyond simplistic container-based counts to provide a potentially more realistic appraisal of accessibility in situations where detailed patterns of actual use are unavailable to researchers. FCA models can be further refined if appropriate empirical evidence is available; for example concerning the distances/times people are prepared to travel to reach specific types of facilities, or concerning those infrastructure characteristics that are most valued amongst different demographic groups. As O'Reilly et al (2015) suggest, based on an analysis of supply-side features associated with the use of swimming pools and ice rinks, and measures of the potential attractiveness (*'Gravitas'*) of such facilities for the 'sportscape' in Toronto, Canada, few studies to date in the sports management or sports geography literature have attempted to differentiate the type of facility characteristics that can, when combined, contribute to influencing levels of participation. Although not the focus of the present study this can be accommodated within FCA models by restricting access to be measured to a sub-set of facilities of a suitable standard or type (should such datasets become more widely available).

2.3 Enhancements to FCA techniques

FCA scores are simple to interpret and take into account the geographical distribution of both the supply of and demand for a service. However, a criticism made of the original FCA formula is that it takes no account of proximity within the computed catchments (Luo and Qi,

2009). This means the same FCA score can arise when service supply points are located far from a given demand point, but still inside the catchment, as when they are located very close by. To address this issue Luo and Qi (2009) proposed an Enhanced Two-Step Floating Catchment Area (E2SFCA) formulation which incorporates an additional distance-weighting term into the model and ensures that nearby service supply locations generate higher FCA scores than those located further away. E2SFCA requires the user to select an appropriate distance-decay function, and its exact form has been subject to some debate and empirical analysis (Wang, 2012). The simplest solution is a linear-decay function whereby the weighting factor for two points coincident in space is 1.0, while a supply or demand point located at the user-specified threshold distance is weighted 0.0, with distances between these two extremes scaled proportionally in a linear fashion.

2.4 Applications of FCA in Sports Geography

E2SFCA models have been applied in a number of policy areas such as access to health services (Dai, 2010; Ngui and Apparicio, 2011; Dewulf et al., 2013) and public transport opportunities (Langford et al., 2012). However, few publications to date have used FCA to measure access to sport facilities. One exception is Cutumisu and Spence (2012) who were concerned with identifying the contribution of perceived and objective measures of access to playing fields on self-reported physical activity levels for a sample survey group of almost 2900 adults in Edmonton, Canada. They used a 1500m street network distance (equivalent to a 15 minute pedestrian trip) to sports fields, a negative exponential function for impedance and differential weights applied to three travel zones at 500m increments from the centroids of the postcodes in which the households of respondents were located. An E2SFCA score was assigned to the postcode of each respondent in the sample to compare levels of physical activity and individual demographic variables with objective and perceived measures of

accessibility. In contrast with perceived access to facilities, where no association was found, their results suggested that individuals with higher FCA scores were more likely to be physically active. This led the researchers to suggest that “objective and subjective environments may influence behaviour independently” (Cutumisu and Spence, 2012; p 307).

There are, however, on-going debates concerning the threshold distance used to define the ‘immediate recreational environment’ for different activities, the types of facilities or opportunities to include in such assessments, the exact form of distance-decay parameter employed in the models, and the influence of different modes of travel (walking, cycling, and private versus public transport) to such opportunities. Such methodological concerns could, it is suggested, be influencing the results from such studies and could account for the inconsistent associations regarding the role of access to recreational centres found in previous studies (Kaczynski and Henderson, 2007). As Cutumisu and Spence (2012; p. 308) conclude, the willingness of people to travel further to access facilities for some activities suggests that “more exploratory studies are necessary to determine the extent to which distance influences the use of various types of facilities”. This suggestion supports the adoption of tools such as that described in this study, which draw upon a regularly updated database of recreational facilities and that include important service characteristics (e.g. opening times, private/public status, and other ‘attractiveness’ and quality measures), to be used to test findings from a number of policy scenarios. Furthermore, the ability to consider the provision of facilities in relation to the likely demand emanating from different population sub-groups, such as those of a specific age range, ethnicity or gender (Wang, 2007) suggest that the tools described in the next section could have wider appeal for sports policy makers concerned with promoting the use of sports facilities and targeting interventions concerned with increasing levels of participation.

3. An add-in tool to measure accessibility to sport facilities

A key component of this study has been the creation of an add-in tool for the ArcMap™ GIS to facilitate easy computation of E2SFCA scores and several other accessibility metrics. This tool is made freely available through this Journal's supplemental material website with the aim of encouraging the wider use of FCA analyses by GIS non-experts. Once installed it is activated via a toolbar button, and when running presents a sequence of bespoke menus through which modelling parameters and data sources are specified before computation is undertaken. In the menu interface illustrated in Figure 1 the aim is to measure access to swimming pools across Wales using a population denominator recorded at Lower Super Output Area (LSOA) level; an administrative unit of the UK Census of Population with a mean population of around 1500 residents (roughly approximating the US Census Block Group).

A user of the tool first identifies the network dataset used to compute times or distances between supply and demand points, selecting from options presented in a drop-down list. A second drop-down presents all available impedance fields within the chosen network layer. These typically include a distance, and often also a time value, for each network edge element (i.e. the distance, or time, taken to traverse each transport segment). The user then specifies the threshold distance (or time) parameter for the FCA model. This is a critical setting as it determines the size of the catchment area constructed around each supply and demand point, as previously described. This value may simply be estimated by the user, but preferably a figure based upon an empirical analysis of the preparedness of the population to travel to reach a particular service type should be used (Spinney and Millward, 2013).

Next the user identifies the ArcMap map layers that define the locations and characteristics of service supply and demand points. In the example shown in Figure 1 a map layer containing

swimming pools represents service supply points, and in this particular instance an attribute field stating the number of lanes at each pool is used as a measure of service capacity at each pool site. Likewise, a layer named 'LSOA centroids' is selected to represent population demand points, using an attribute field that reports the total number of residents at each site. Finally, the user may select an additional attribute field from the demand point layer to be carried over into the results table. This feature allows an area identity code to be added to the output table to help facilitate the mapping of results.

[FIGURE ONE INSERTED ABOUT HERE]

The user is then asked to specify whether a simple or enhanced FCA computation is to be performed. If the latter option is selected further inputs allow the precise nature of the distance-decay function to be specified. Once all modelling parameters are set the user initiates the calculation of accessibility scores. This deploys various functions from within the ArcGIS Network Analyst Extension and reports back to the user messages concerning the current status of the task. On completion a number of output metrics are written into a table in which successive columns present the following: the identity of the demand point; a demand point carry-over attribute as described earlier; the identity of the nearest supply point; the distance or time to the nearest supply point; the total number of supply points within the specified catchment size; the average distance/time to these points; and finally the simple or enhanced FCA score. These metrics are typically linked back to a map layer of the census tracts in order to reveal any spatial patterns that may be present.

4. Analysing the provision of bowling greens in Wales using FCA techniques

Within Sport Wales, the FCA add-in tool is accompanied by an ArcGIS™ geodatabase as described below, and a set of example exercises that provide training in the use of FCA

techniques for measuring access to sports facilities. Like comparable organisations in other countries, Sport Wales collate and maintain important databases on the locations and types of sporting facilities that are available across Wales. These clearly have the potential to help analyse factors influencing patterns in provision, the uptake of services, and the levels of physical activity seen amongst the served population. The ESRI geodatabase used with the FCA tool is a collection of geographic datasets of different formats and types stored in a common file system folder and in this study consists of a GIS map layer holding the location of all sports facilities in Wales contained within the Sport Wales Facilities Dataset. This dataset details a wealth of facility types such as swimming pools, squash courts, indoor and outdoor tennis courts, ski slopes, ice rinks, indoor and outdoor athletics tracks, golf courses, grass pitches, health and fitness centres, and so on. Furthermore, a rich set of attributes are recorded for these facilities with information on, for example, the area of an ice rink, the number of tennis courts available, the presence or absence of floodlighting at grass pitches, the floor area of a sports hall, and so on. The geodatabase also holds an ERSI network dataset constructed from Ordnance Survey's Open Roads™ data, which are issued under an open access licence. This network includes both a distance and a time impedance value for each road segment. Finally the geodatabase contains open source data relating to the 2011 UK Census of Population. These include population weighted centroids and census tract boundaries for Output Areas (OA) which are the smallest geographical level for reporting census estimates (with an average resident population of just over 300) and Lower Super Output Area (LSOA) administrative units which are aggregates of OAs with an average population of 1500, along with several commonly used attribute tables for key population counts including breakdowns by gender and age group.

Together the add-in tool and its accompanying geodatabase provide a rich analytical environment in which FCA modelling can be conducted with relative ease by a non-expert

GIS user. To demonstrate the potential of this environment a case study is presented here to assess the spatial provision of bowling greens across Wales. A total count of 235 sites and 262 greens (because 27 sites possess two greens) are reported by the database, the spatial distribution of which across Wales is shown in Figure 2. To examine the spatial provision of these greens using the container approach we would compute the numbers falling inside each spatial unit of analysis, then divide this tally by the relevant population denominator to obtain a ratio of the number of greens per head of population. Although there are concerted efforts by the Welsh Bowling Association to promote this sport amongst all age groups, perhaps stereotypically it is associated with a more elderly demographic. To reflect this *potential* bias, in the absence of a detailed small area profile of the ages of participants and in order to illustrate how carefully tailored supply/demand relationships might be utilised, we employ a count of the population aged 45 and over in each administrative unit (which adds up to a total population of a little over 1,375,000 across Wales). Figure 3 illustrates the resultant spatial pattern when LSOAs are used as the spatial unit of analysis.

[FIGURES TWO AND THREE INSERTED ABOUT HERE]

Although it is desirable to conduct the analysis at this relatively fine spatial scale the outcome from a container model raises an immediate problem. A count of three bowling greens was found in one Lower Super Output Area (LSOA), a count of two in 12 others, and one bowling green was found in a further 208 LSOAs. But the vast majority of LSOAs (1688 in total) contain no bowling green at all. The container approach is clearly unhelpful in studying the spatial relationship between bowling greens and population distribution when conducted at this fine level of spatial detail. To have any useful purpose much coarser spatial scales must be used such as Local Authority District (LAD) zones, which represent local governments in the UK. There are currently 22 such zones within Wales and these larger

tracts allow a more meaningful range of supply-side scores to be recorded, ranging in this instance from a minimum count of 1 green to a maximum of 26. Figure 4 shows the spatial distribution of these scores after they have been normalised by their respective age 45+ population counts.

[FIGURE FOUR INSERTED ABOUT HERE]

Mapping sports provision at such coarse scales may still be useful when the management of the resources and the decision making processes associated with them is performed strictly within these borders. So the container approach can be attractive for local administrators despite its obvious drawbacks. However, at this scale any understanding of the patterns of provision in relation to socio-economic characteristics of an area, or efforts to link service provision to detailed data on sports participation rates and physical activity levels is problematic. No differentiation of accessibility is depicted within the LAD boundaries, and the analysis fundamentally assumes that no cross-border activity takes place between adjacent zones. As discussed earlier, network distance approaches are often called on by sports geographers and others when wishing to map accessibility at detailed spatial scales. Figure 5 shows the spatial patterns revealed by calculating the nearest network distance to a bowling green from each LSOA centroid. This is a potentially useful output for a whole host of policy purposes and may also be informative for the general public interested in knowing the location of the nearest sports facility. Hence this methodology has been used by organisations such as ‘Sport England’ in enabling web-based interrogation of their sport facility database (Sport England, 2016). However, as noted previously, although the distance metric may be based upon sophisticated network analysis, no account is taken of the local population size, and hence the level of demand that might be expected to be placed upon the service at any particular location. In many ways this map is not so very different to the point

map presented in Figure 2 in terms of the information it portrays. High scores simply reflect proximity to a bowling green and so largely mirror the spatial distribution of facilities themselves without taking into account the level of demand likely to be placed upon them.

[FIGURE FIVE INSERTED ABOUT HERE]

The FCA methodology allows a very different perspective to the simplistic approaches described above. Figure 6 shows E2SFCA accessibility scores computed for LSOAs with respect to bowling greens and with demand arising from the age 45+ population sub-group. This example used a 15km FCA distance threshold and a linear distance-decay function which in the absence of detailed data on the utilisation of these facilities was estimated as a reasonable approximation of the distance players would be prepared to travel (but of course could be replaced with more accurate data should this be available from surveys of participants). In this map the relatively dense provision of greens present in the south-east of Wales are clearly tempered by an equally large aged 45+ population that is able to reach them. Many rural areas remain poorly provided for, but where greens do exist there is a tendency for the local E2SFCA scores to be quite high simply because these facilities are shared amongst a small population base. The spatial detail in the FCA analysis also reveals interesting ‘hot spots’ on the west and north coasts of Wales which may be worthy of further detailed study to understand historical reasons for the patterns of local provision. The greater spatial detail helps to raise potentially interesting questions from both a methodological and policy standpoint. For example, does a census-based residential population count offer a sensible demand estimation if no account is taken of tourist-based populations? And do local inhabitants benefit from the provision of facilities that are perhaps at least partly supported by the presence of a tourist population?

[FIGURE SIX INSERTED ABOUT HERE]

Finally, Figure 7 conducts the same analysis but using travel time rather than distance (a travel time limit of 20 minutes was specified). Results are broadly similar to the distance based analysis, but subtle differences are evident such as the raised access levels amongst LSOAs on major transport routes in mid and north Wales. The poor provision in south-west Wales persists, whilst that in the far south-east must be treated with some caution due to potential boundary effects (i.e. any greens in neighbouring English LSOAs were not accounted for). The distance/time thresholds adopted and distance-decay function applied are easy to adjust using the bespoke tool should empirical evidence become available to help inform these decisions, or alternatively if the analyst wishes to conduct a sensitivity analysis in respect to these modelling parameters.

[FIGURE SEVEN INSERTED ABOUT HERE]

5. Discussion and Conclusions

Evidence to date on the role of perceived or objective measures of accessibility on levels of sport participation or physical activity tend to be contradictory, but there is a growing realisation that policy makers need a sound evidence base with which to measure the availability of recreational resources, as well as the types of facilities available at each location. Previous research in this area concerned with deriving objective measures of sporting infrastructure tend to be based on the use of fixed administrative units to estimate counts of facilities/opportunities or densities in relation to potential demand. This may be suitable for certain policy purposes but, as this study has highlighted, their use is fundamentally flawed where people are travelling outside their immediate residential or workplace area to access facilities. This study draws on a rich and regularly updated source of data on private and public sports facilities maintained by Sport Wales to demonstrate the

potential to derive more sophisticated measures of spatial accessibility to sport facilities using floating catchment area models and network-based distances/times. However, the complexity of the FCA methodology means that there is a real need to develop customised tools to undertake the computation required and thus enable non-GIS specialists to conduct such analyses. As demonstrated in this study the outputs from FCA models, which are still essentially a ratio of supply-to-demand values recording the provision of sports facilities per unit of population, are intuitively interpretable by policy makers concerned with identifying geographic disparities in the provision of services.

Such tools may in the future be further enhanced in a number of key regards. Firstly, the tools described here are currently designed to run in a PC desktop environment and use functionality supplied in a commercial proprietary GIS package (ArcGIS). One potential avenue for development is to make similar tools available that operate in an open source GIS environment such as QGIS. Furthermore, there is potential to migrate away from a desktop platform and to offer FCA computations through a web browser interface, possibly with the underlying analytical functions being performed server-side through technologies such as PostGIS and pgRouting. This would enable substantial upscaling in performance and data volume handling, in addition to the potential to allow public access to ‘on-the-fly’ analyses. Secondly, the models currently assume that all transport is via private means on recognised road networks. Future versions of these tools could incorporate alternative modes of transport, such as public buses, cycling, and so forth. Grow et al. (2008), for example, in a study of access amongst children have demonstrated how active transport modes such as cycling and walking are strongly associated with frequency of use of sites such as indoor recreational opportunities. More research is needed on how such factors vary in relation to other socio-demographic groups. Researchers have already begun to investigate how data on public transport provision and commuter patterns can be used to incorporate complex travel

behaviour into FCA-based accessibility calculations (see for example, Fransen et al., 2015; Langford et al., 2012; Mao and Nekorchuk, 2013). Thirdly, by incorporating a temporal element that includes the opening times of facilities together with factors such as public transport availability and likely variations in population demand from residence or work place origins, these models could be further refined to include individual activity schedules. The addition of such added functionality within the customised tools described in this study would enable changes in the sporting and transport infrastructure provision to be actively monitored.

More generally, this study highlights how bespoke GIS tools can be used to provide a baseline with which to monitor the impacts of future changes in provision particularly given the current financial pressures facing local authorities and other sport providers in the UK (Sport Wales, 2016). Previous studies have drawn attention to the importance of geography as an “enabler” or “inhibitor” for engagement levels in sport. As O’Reilly et al (2015; p. 296) conclude “sport managers and sport policy makers need to better understand how they might utilise geographical notions of distance decay, range, and threshold to better understand the nature of sport engagement”. The tool implemented in the present study provides the means with which to investigate such trends but also calls for a more realistic conceptualisation of potentially influential neighbourhood areas than those based on crude administrative units. This is illustrated in this study with respect to the spatial patterns revealed in the provision of bowling greens in Wales. This analysis could be supplemented by additional information (if available) on the costs of use, quality of bowling greens, or other attributes such as physical access. In particular, the potential to identify the communities that could benefit from increased levels of provision for different types of facilities provides a potentially powerful tool for policy makers charged with improving participation rates for demographic groups

that are consistently identified in national surveys as having the highest levels of physical inactivity.

Findings from this research also have important policy implications. In a recently published policy blueprint document for sport and active recreation (2016), Sport Wales recognise that in order to meet the national targets set for improving levels of physical activity, “the facilities that can provide those opportunities must be inclusive, attractive, accessible and efficient and they must be what people and communities need” (Sport Wales, 2016; p. 3). In order to measure such opportunities, Sport Wales gathers information on the locations and types of sporting facilities available in Wales both to support administrative functions, inform the targeting of capital investment schemes and monitor the changing status of the sporting ‘facilities landscape,’ including the potential rationalisation or co-location of facilities. As in many other international contexts, sports participation rates continue to be lower in more deprived communities compared to the national average (Sport Wales, 2013) and the potential reasons for such patterns, including the potential role of variations in the availability of sporting opportunities, are subject to on-going research by those charged with funding such facilities and supporting leisure activities (Sport Wales, 2013). Although not the primary focus of the present study, it is posited that findings from such studies could contribute to further research concerned with investigating the wider implications of changes in the availability of sport facilities on participation rates and levels of physical activity for leisure activities such as lawn green bowling which could enhance existing approaches to measuring such impacts (Halonon et al., 2015). The finding that average travel times to leisure centres by walking or using public transport (18 minutes compared to a Wales average of 28 minutes) tend to be lower for the 10% most deprived areas of Wales than the national average, suggests more research is needed to examine the importance of other supply-side factors such as quality and programming in influencing such patterns (Sport Wales, 2012).

The types of tools described in this study, and illustrated with reference to one type of facility, have the potential to help researchers examine variations in access to sporting opportunities at a variety of spatial scales in relation to potential demand. Our future research programme will draw on such findings to investigate how such variations in accessibility impact on factors such as participation rates, levels of physical activity and health outcomes.

6. Acknowledgements

This study is based on research funded by Sport Wales under the Illuminate Scheme. The work was supported by the Wales Institute of Social and Economic Research, Data and Methods (WISERD). WISERD is a collaborative venture between the Universities of Aberystwyth, Bangor, Cardiff, South Wales and Swansea. The research that this publication relates to was funded by the ESRC (Grant number: ES/L009099/1). We thank Sport Wales for the provision of data on recreational facilities within Wales. Census data were downloaded from NOMIS, a service provided by the Office for National Statistics (ONS) to provide free access to UK Census of Population data. This information is licensed under the terms of the Open Government Licence. Maps contain Ordnance Survey data © Crown copyright and database right 2013. Additional data are sourced from third parties, including public sector information licensed under the Open Government Licence v1.0. The views and opinions expressed in this paper do not necessarily reflect those of these organisations.

7. References

Adams, M.A., Todd, M., Kurka, J., Conway, T.L., Cain, K.L., Frank, L.D. and Sallis, J.F. (2015) Patterns of walkability, transit and recreation environments for physical activity, *American Journal of Preventative Medicine*, forthcoming.

Billaudeau, N., Oppert, J-M., Simon, C., Charreire, H., Casey, R., Salze, P., Badariotti, D., Banos, A., Weber, C. and Chaix, B. (2011) Investigating disparities in spatial accessibility to and characteristics of sport facilities: Direction, strength ,and spatial scale of associations with area income, *Health and Place*, 17, 114-121.

Brownson, R.C., Hoehner, C.M., Day, K., Forsyth, A. and Sallis, J.F. (2009) Measuring the built environment for physical activity: State of the Science, *American Journal of Preventative Medicine*, 36(4 Suppl), s99-s123.

Cutumisu, N. and Spence, J.C. (2012) Sport Fields as Potential Catalysts for Physical Activity in the Neighbourhood, *International Journal of Environmental Research and Public Health*, 9, 294-314

Dai, D. (2010) Black residential segregation, disparities in spatial access to health care facilities, and late-stage breast cancer diagnosis in metropolitan Detroit, *Health and Place*, 16 (5), 1038–1052.

Dewulf, B., Neutens, T., De Weerd, Y. and Van de Weghe, N. (2013) Accessibility to primary health care in Belgium: an evaluation of policies awarding financial assistance in shortage areas, *BMC Family Practice*, 14 (1), 122.

Diez-Roux, A.V., Evenson, K.R., McGinn, A.P., Brown, D.G., Moore, L., Brines, S. and Jacobs, D.R. (2007) Availability of recreational resources and physical activity in adults, *American Journal of Public Health*, 97(3), 493-499.

Estabrooks, P.A., Lee, R.E. and Gyurcsik, N.C. (2003) Resources for physical activity participation: does availability and accessibility differ by neighbourhood socio- economic status? *Annals of Behavioural Medicine*, 25(2), 100–104.

Fransen, K., Neutens, T., De Maeyer, P. and Deruyter, G. (2015) A commuter-based two-step floating catchment area method for measuring spatial accessibility of day care centres, *Health and Place*, 32(1), 65-73.

Grow, H.M, Saelens, B.E., Kerr, J., Durant, N.H., Norman, G.J. and Sallis, J.F. (2008) When are youth active? Roles of proximity, active transport and built environment, *Medicine and Sport Science in Sports and Exercise*, 40(12), 2071-2079.

Hallmann, K., Wicker, P., Breuer, C. and Schuttoff, U. (2011) Interdependency of sport supply and sport demand in German metropolitan and medium-sized municipalities – findings from multi-level analyses, *European Journal for Sport and Society*, 8(1/2), 65-84.

Hallmann, K., Wicker, P., Breuer, C. and Schönherr, L. (2012) Understanding the importance of sport infrastructure for participation in different sports – findings from multi-level modeling, *European Sport Management Quarterly*, 12 (5), 525-544.

Halonen, J.I., Stenhom, S., Kivimäki, M., Pentti, J., Subramanian, S.V., Kawachi, I. and Vahtera, J. (2015) Is change in availability of sports facilities associated with change in physical activity? A prospective cohort study, *Preventive Medicine*, 73 (1), 10-14.

Higgs, G., Langford, M. and Norman, P. (2015) ‘Accessibility to sports facilities in Wales: A GIS-based analysis of socio-economic variations in provision’, *Geoforum*, 62,105-120.

Hillsdon, M., Panter, J., Foster, C. and Jones, A. (2007) Equitable access to exercise facilities, *American Journal of Preventative Medicine*, 32(6), 506-508.

Humpel, N., Owen, N. and Leslie, E. (2002) Environmental factors associated with adults’ participation in physical activity: A review, *American Journal of Preventative Medicine*, 22(3), 188-199.

Jones, S.A., Moore, L.V., Moore, K., Zagorski, M., Brines, S.J., Diez-Roux, A.V. and Evenson, K.R. (2015) Disparities in physical activity resource availability in six US regions, *Preventive Medicine*, 78 (1), 17-32.

Kaczynski, A.T. and Henderson, K.A. (2007) Environmental correlates of physical activity: a review of evidence about parks and recreation, *Leisure Sciences*, 29, 315-354.

Karusisi, N., Thomas, F., Meline, J. and Chaix, B. (2013) Spatial accessibility to specific sport facilities and corresponding sport practice: the RECORD Study, *International Journal of Behavioral Nutrition and Physical Activity*, 2013, 10:48

Kim, J. and Nicholls, S. (2016) Influence of the measurement of distance on assessment of recreation access, *Leisure Sciences*, 38(2) 118-139.

Kirby, J., Levin, K.A. and Inchley, J. (2013) Socio-environmental influences on physical activity among young people: a qualitative study, *Health Education Research*, 28(6), 954-969.

Langford, M., Fry, R. and Higgs, G. (2012) Measuring transit system accessibility using a modified two-step floating catchment technique, *International Journal of Geographical Information Science*, 26(2), 193-214.

Limstrand, T. (2008) Environmental characteristics relevant to young people's use of sports facilities: A review, *Scandinavian Journal of Medicine and Science in Sports*, 18, 275-287.

Luo, W. (2004) Using a GIS-based floating catchment method to assess areas with shortage of physicians, *Health and Place*. 10, 1-11.

Luo, W. and Qi., Y. (2009) An enhanced two-step floating catchment area (E2SFCA) method for measuring spatial accessibility to primary care physicians, *Health and Place*, 15, 1100-1107.

Luo, W. and Wang, F. (2003) Measures of spatial accessibility to health care in a GIS environment: synthesis and a case study in the Chicago region, *Environment and Planning B*, 30 (6), 865–884.

Macintyre, S. (2007) Deprivation amplification revisited; or, is it always true that poorer places have poorer access to resources for healthy diets and physical activity? *International Journal of Behavioural Nutrition and Physical Activity*, 4:32.

Mao, L. and Nekorchuk, D. (2013) Measuring spatial accessibility to healthcare for populations with multiple transportation modes, *Health and Place*, 24, 115–122.

Moore, L.V., Diez-Roux, A.V., Evenson, K.R., McGinn, A.P. and Brines, S.J. (2008) Availability of recreational resources in minority and low socio-economic status areas, *American Journal of Preventative Medicine*, 34(1), 16-22.

Neutens, T. (2015) Accessibility, equity and health care: review and research directions for transport geographers, *Journal of Transport Geography*, 43(1), 14-27.

Ngui, A.N. and Apparicio, P. (2011) Optimizing the two-step floating catchment area method for measuring spatial accessibility to medical clinics in Montreal, *BMC Health Serv. Res.*, 11 (1), 166.

O'Reilly, N., Berger, I.E., Hernandez, T., Parent, M.M. and Seguin, B. (2015) Urban sportscares: An environmental deterministic perspective on the management of youth sport participation, *Sport Management Review*, 18(2), 291-307.

Paez, A., Scott, D.M. and Morency, C. (2012) Measuring accessibility: positive and normative implementations of various accessibility indicators, *Journal of Transport Geography*, 25(1), 141-153.

Pascual, C., Regidor, E., Martinez, D., Elisa Calle, M. and Dominguez, V. (2009) Socioeconomic environment, availability of sports facilities and jogging, swimming and gym use, *Health and Place*, 15, 553-561.

Persson, A. and While, A. (2011) Physical activity among older people and related factors, *Health Education Journal*, 71(2), 144-153.

Powell, L.M., Slater, S., Chaloupka, F.J. and Harper, D. (2006) Availability of physical activity-related facilities and neighbourhood demographic and socio-economic characteristics: A national study, *American Journal of Public Health*, 96(9), 1676-1680.

Powell, L.M., Chaloupka, F.J., Slater, S.J., Johnston, L.D. and O'Malley, P.M. (2007) The availability of local-area commercial physical activity related facilities and physical activity among adolescents, *American Journal of Preventive Medicine*, 33, S292-S300.

Prins, R.G., Mohnen, S.M., Lenthe, F.J., Brug, J. and Oenema, A. (2012) Are neighbourhood social capital and availability of sports facilities related to sports participation among Dutch adolescents? *International Journal of Behavioral Nutrition and Physical Activity*, 9:90.

Prins, R.G., Oenema, A., van der Horst, K. and Brug, J. (2009) Objective and perceived availability of physical activity opportunities: differences in associations with physical activity behaviour among urban adolescents, *International Journal of Behavioral Nutrition and Physical Activity*, 6:70.

Spinney, J.E.L. and Millward, H. (2013) Investigating travel thresholds for sports and recreation activities, *Environment and Planning B: Planning and Design*, 40, 474-488.

Sport England (2016) "Local Sport Profile" Sport England.

Accessed November 24th 2016.

<http://localsportprofile.sportengland.org/>

Sport Wales (2012) *Appropriate Facilities: evidence to support the Community Sport Strategy*, Cardiff, Sport Wales.

Sport Wales (2013) *A Vision for Sport in Wales*, Cardiff, Sport Wales.

Sport Wales (2016) *Facilities for Future Generations: A blueprint for sport and active recreation in Wales*, Cardiff, Sport Wales.

Sterdt, E., Liersch, S. and Walter, U. (2014) Correlates of physical activity of children and adolescents: A systematic review of reviews, *Health Education Journal*, 73 (1), 72-89.

Talen, E. and Anselin, L. (1998) Assessing spatial equity: an evaluation of measures of accessibility to public playgrounds, *Environment and Planning A*, 30, 595-613.

Wang, L. (2007) Immigration, ethnicity, and accessibility to culturally diverse family physicians, *Health and Place*, 13(3), 656-71.

Wang, F. (2012) Measurement, optimization and impact of the healthcare accessibility: a methodological review, *Annals of the Association of American Geographers*, 102, 1104-1112.

Wendel-Vos, W., Droomers, M. Kremers, S., Brug, J. and van Lenthe, F. (2007) Potential environmental determinants of physical activity in adults: a systematic review, *Obesity Reviews*, 8, 425-440.

Yang D-H., Goerge R., and Mullner, R. (2006) Comparing GIS-Based Methods of Measuring Spatial Accessibility to Health Services, *Journal of Medical System*, 30(1), 23-32.