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Estimating Catchment Area Population Indicators Using Network Analysis

J Cullinan\textsuperscript{a}, S Hynes\textsuperscript{a} and C O’Donoghue\textsuperscript{b}

ABSTRACT

This paper proposes an approach to estimating catchment area population indicators (CAPIs) using GIS-based network analysis. Specifically it considers how ‘GeoDirectory’, a geodatabase containing the spatial co-ordinates of every building in the Republic of Ireland, can be used in conjunction with estimated service areas to calculate the number of residential buildings within a catchment area. It also demonstrates the usefulness of GeoDirectory in undertaking route analysis for estimating journey distances and times. Two small-scale recreation forest sites in County Galway are considered by way of illustration: Barna Wood and Renville Forest Park. CAPIs are estimated for the two sites using distance-based service areas as well as isochrone surfaces, and comparisons are made to estimates based on measures of Euclidean distance. The analysis suggests that network-based service areas are useful for deriving catchment population indicators, that road density has a significant impact on catchment area size and that caution must be exercised with respect to travel speed assumptions when estimating isochrone surfaces.

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Introduction

Catchment areas are generally defined as geographical entities such as the surrounding area served by an institution or facility. Accurate estimates of catchment areas, catchment populations and their associated characteristics are important inputs in many public policy and private investment decisions. According to Veal (2002) catchment areas “can be an important basis for planning” the location of recreation and leisure facilities and consequently for resource allocation decisions. Catchment area analysis is also identified as important for decision-making in other areas. For example, ERPHO (2003) assert that “the concept of catchment underlies the study of the geographical and demographic distribution of a health care service.”

The principal aim of this paper is to propose and illustrate an approach for estimating catchment area population indicators for outdoor recreation sites using a geographical information system (GIS). In the case of outdoor recreation activities, the economic value of a non-priced, open-access, amenity can be thought of as a function of the number of visits to the amenity - see for example Hynes et al. (2007) - as well as the duration of these visits. The total number of visits is determined, in part, by the distances that individual recreationalists must travel to visit the site. One way of considering this is to examine the catchment area population around a recreation site. Thus, catchment estimates can act as useful inputs for considering visitor numbers, overall usage and economic value.

To this end we consider how GeoDirectory, a database containing the spatial co-ordinates of every building in the Republic of Ireland, may be used in conjunction with GIS-based ‘Network Analysis’ (NA), to provide indicators of potential demand at recreation sites. We also demonstrate the usefulness of GeoDirectory in undertaking a route analysis for estimating journey distances and times to outdoor amenities. Two small-scale recreation forest sites in County Galway are considered in illustrating the approach: Barna Wood and Renville Forest Park. CAPIs are estimated for each site using both distance-based service area analysis and isochrone surface analysis and estimates are compared to measures based on Euclidean distance. Our aim is to present a non-technical account of the approach in order to demonstrate the benefits of using network analysis and GeoDirectory to both GIS users and non-
users alike. The proposed approach is most applicable for considering amenities and facilities with relatively small catchment areas.

The paper is structured as follows. In the next section we introduce GeoDirectory and discuss how it may be used in conjunction with GIS-based network analysis. Following this we set out our approach for using service area analysis with GeoDirectory in order to estimate catchment area population indicators. The final section presents our concluding remarks.

**Using GeoDirectory in Network Analysis**

*Introduction to GeoDirectory*  
GeoDirectory is a geodatabase of all buildings in Ireland and is developed by An Post and Ordnance Survey Ireland (OSi). Each of the approximately 2 million building records contained in GeoDirectory (as of July 2007) include a standardised postal address (i.e. one that conforms to a uniform An Post predetermined standard), details about whether the building is used for commercial or residential purposes, and the spatial (x,y) coordinates or geocodes\textsuperscript{ii} which accurately locate the centre point of each building to within one metre. GeoDirectory also identifies buildings that are derelict, vacant, invalid and/or under construction and also distinguishes between residential buildings that are houses and apartments. The data and information contained within GeoDirectory enables a range of analyses. For example, Meredith (2007) provides an assessment of the utility of Geodirectory for monitoring the implementation of the National Spatial Strategy in Ireland, while Kalogirou and Foley (2006) use the database to help develop hospital accessibility measures.

GeoDirectory data for County Galway from 2007 is used in this paper. The total number of all buildings in the county is estimated at 117,052, comprising 99,622 residential addresses linked to 89,745 separate residential buildings with associated spatial coordinates. Some buildings, such as apartment blocks, may contain more than one residential address. Figure 1 presents the spatial distribution of residential buildings for an area in Galway City along with a representation of the road network illustrating how GeoDirectory can be mapped using a GIS with other layers of geo-information. Buildings classified as commercial only or of unknown usage are
excluded from Figure 1 and from the subsequent analysis as are any buildings classified as derelict, vacant, invalid and/or under construction.

Figure 1: Spatial distribution of residential buildings in an area of Galway City

Source: An Post GeoDirectory 2007 and data supplied under Licence No. 6155 from OSI

Network Analysis

The application of geographic information science and systems to transportation problems is known as GIS-T and according to Fischer (2006) “represents one of the most important application areas of GIS technology today”. GIS-T applications are commonly used by transportation agencies to consider a broad range of transportation issues, including infrastructure planning, design and management as well as safety, travel demand and environmental issues – Rodrigue et al. (2006). GIS-T is also routinely applied in areas such as logistics, emergency services and health care planning, particularly in relation to accessibility issues. For example, Kalogirou and Foley (2006) use a GIS framework to model accessibility to hospitals in Ireland, while Murphy and Killen (2007) assess transportation accessibility issues in relation to possible locations for a new national paediatric hospital in Ireland.

One specific type of GIS-T is network analysis, a process to find solutions to network (often transportation-oriented) problems, and used in this paper. According to Fischer
“both geographic information systems and network analysis are burgeoning fields, characterised by rapid methodological and scientific advances in recent years”. For our purposes network analysis can be considered as a GIS technique or process used to calculate the distances covered and times taken in making a journey on a network, and the ‘Network Analyst’ extension within ‘ArcGIS’ was used.

The ArcGIS Network Analyst extension contains four different network ‘solvers’. The ‘route solver’ creates an optimal route from a specified start point to a specified end point via the given network and according to a specified impedance – this is known as ‘route analysis’. If the impedance is time, the optimal route is the quickest route. If the impedance is distance, the optimal route is the shortest route. The route solver estimates the journey distance, time and direction associated with the optimal route. Closely related, the ‘origin-destination cost matrix solver’ solves for a matrix of optimal routes between a number of specified origin and destination points. The optimal route problem is a classic problem within GIS-T and can be modelled using both of the above solvers. The ‘closest facility solver’ on the other hand identifies the closest facility (or facilities) to a specified location. The solver allows the user to specify the direction of travel and display the best route to or from the facility, return the travel cost for each route, and display directions to each facility.

The fourth solver is the ‘service area solver’, which calculates service areas around a point or location on a network. A network service area is a region that encompasses all accessible points on the network (e.g. streets) within a specified impedance. For instance, a 5-kilometre (km) service area for a point includes all points on the network that are within 5kms of that point. On the other hand a 10-minute service area for a point includes all points on the network that are within 10 minutes travel time of that point. So, different impedances may be chosen in defining the service area, and these service areas can be used to evaluate accessibility. Once estimated and combined with spatial data on individuals or households, service areas can be used to determine catchment area populations.

Using GeoDirectory in Route Analysis

The GeoDirectory database can be used in conjunction with all of the solvers discussed above, including route analysis, where geo-referenced road network data is
available. In the subsequent analysis vector data from the OSi 1:50,000 Discovery Series dataset is used. The data was transformed to a series of vector ‘shapefiles’ containing the different elements or classes of the road network in Ireland, such as motorways, national primary, national secondary, third class and fourth class roads. This data forms the base on which the road network database is created or ‘built’.

Before GeoDirectory buildings can be used as start or end points in a route analysis they need to be ‘snapped’ to the road network. Snapping is the process of moving a feature (such as a GeoDirectory building) to coincide exactly with the coordinates of another feature (say the road network) within a specified snapping distance, or tolerance. Prior to being snapped the spatial coordinates of a GeoDirectory building may not be situated precisely on the road network. Each of the snapped locations however represents a point on the road network and can be used in a route analysis. Figure 2 presents an example of the process of snapping GeoDirectory buildings to the road network. The road network is presented as a thin line, while the spatial coordinates of the GeoDirectory buildings are represented by the lighter dots. During the snapping process these households are moved to the nearest point along the road network, in effect becoming ‘connected’ to the road network – they are represented by the darker dots and positioned on the road network.

The spatial coordinates of other points of interest, say a recreation site, can also be added to the map. In Figure 2 for example, the spatial coordinates of Barna Wood have been added. Since these coordinates do not exactly coincide with the road network the coordinates are also snapped. This represents an example of a potential journey end point in a route analysis and the ‘route solver’ can now be used to estimate the optimal travel route to the site from a specified starting point.
Figure 2: Snapping GeoDirectory residential locations and a geo-referenced recreation site to the road network

An example of a route analysis using GeoDirectory is presented in Figure 3 where one specified snapped GeoDirectory building is defined as the starting point of a hypothetical journey and represented by the dot with the number 1. The end-point, Barna Wood, is represented by the dot with the number 2. Figure 3 illustrates, after the route solver has been executed, the most efficient or optimal path for the journey, as the thicker line between the two points. In this particular case the journey distance is estimated as 1.1kms and represents the shortest possible route by road between the two points. Setting an alternative impedance, e.g. journey time, would similarly allow us to estimate the route with the shortest journey time between the two points.
Using Service Areas to Estimate Catchment Area Population Indicators

We now consider how GeoDirectory can be used in conjunction with estimated service areas to develop catchment area population indicators. Service areas based on two different impedances are considered, one based on distance, the other on travel time (also referred to as isochrones). Only a few previous papers have estimated and presented network-based service areas in Ireland, though not in relation to recreation sites. Vega and Reynolds-Feighan (2007) present service areas based on distance around Dublin city centre in a study on residential location and travel-to-work mode choice, while Clifford (2007) estimate service areas along quality bus corridors and Dart stations in North Dublin. In the UK, Brainard et al. (1997) have estimated isochrone surfaces to help predict visitor arrivals to a public-access woodland using a zonal travel cost model, as did Lovett et al. (1997) in considering benefit transfer demand functions. Other UK studies have also considered the potential benefits of utilising GIS and network analysis in recreation demand modelling, including Bateman et al. (1999, 2003) and Jones et al. (2003).
Our aim is to estimate the number of residential buildings within a given proximity of a recreation amenity as an indicator of the catchment area population and a proxy for demand. Before considering the service area analysis however, details relating to the recreation sites are presented.

**Study Sites**

Two forest sites in County Galway are considered to illustrate our approach, Barna Wood and Renville Forest Park. Both forests are relatively small outdoor recreation amenities and while located close to residential areas are not considered tourist destinations in their own right. Barna Wood (henceforth also referred to as Barna) is located in the western suburbs of Galway city. It covers 10.5 hectares, provides walks, trails and picnic facilities and boasts the last natural growing oaks in the West of Ireland. Renville Forest Park (henceforth also referred to as Renville) is located 2 miles from Oranmore village and has a forested area of 18.5 hectares. Renville’s amenities include walks through woodlands, farmland and along the coast, while the forest has a playground, picnic and barbeque facilities on site.

Cahill (2006) recently undertook a visitor survey focussed on recreation activities at the two forests. In total 269 on-site personal interviews were carried out over a period of two months during the summer of 2006. The study found the number and frequency of visits to both amenities to be high with a significant number of people visiting the sites on a daily basis. The mean annual number of trips per respondent to the forests was 68.3 (range 1 – 365). Furthermore, both forests were found to cater for a wide range of uses, from walking, nature walking, dog walking, cycling and picnicking. Among the findings of Cahill (2006) was that “community owned small-scale forestry can contribute enormously to the wellbeing of nearby urban residents, through the provision of outdoor recreational services.”

Table 1 presents a summary analysis of reported travel distances and times to both sites by the survey respondents. This data is informative in determining the parameters in the subsequent service area analyses since, according to Veal (2002), “it is possible to establish the catchment area of a facility by means of a user or visitor survey”. Table 1 shows that, on average, survey respondents travelled 3.6kms to visit Barna Wood and 10.3kms to visit Renville Forest Park, with medians of 1.6kms and
6.4kms respectively. There was however some variation in distances travelled amongst respondents, particularly to Renville, as evidenced by the reported standard deviations and ranges. A closer inspection of the data revealed that the vast majority of total reported trips undertaken to Barna involved travel distances of less than 5kms (94.2%) with almost all visits involving a distance of less than 10kms (99.7%). For Renville, 91.8% of trips involved a distance of less than 10kms, 96.8% a distance of less than 15kms and 98.2% a distance of less than 20kms.

Overall an analysis of travel distances to the sites suggests that in general both forests are visited by persons either living, or staying, in the locality. In the case of Barna Wood, most of the visits are from the immediate vicinity of the forest. Thus, in considering catchment area populations for these sites as a proxy for the total demand for visits, the focus should be on areas that are relatively close to the study sites. According to Hynes and Cahill (2007), “the short average distance travelled and the high average frequency of trips taken is an indication of the use that local residents in particular get from the two case study forest sites.”

Table 1: Analysis of distances travelled to study sites by survey respondents

<table>
<thead>
<tr>
<th></th>
<th>Barna Wood</th>
<th>Renville Forest Park</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>3.6</td>
<td>10.3</td>
</tr>
<tr>
<td>Median</td>
<td>1.6</td>
<td>6.4</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>3.4</td>
<td>16.0</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.8</td>
<td>0.5</td>
</tr>
<tr>
<td>Maximum</td>
<td>12.9</td>
<td>144.8</td>
</tr>
<tr>
<td>Number of observations</td>
<td>66</td>
<td>203</td>
</tr>
</tbody>
</table>

Source: Analysis of data collected by Cahill (2006)

A similar picture emerges from an examination of reported travel time to the sites by the survey respondents. Table 2 shows that on average respondents undertook a journey of 6.8 minutes to visit Barna and 13.3 minutes to visit Renville, with median travel times of 3.0 minutes and 10.0 minutes respectively.
Table 2: Analysis of journey times to study sites by survey respondents (minutes)

<table>
<thead>
<tr>
<th></th>
<th>Barna Wood</th>
<th>Renville Forest Park</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>6.8</td>
<td>13.3</td>
</tr>
<tr>
<td>Median</td>
<td>3.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>6.8</td>
<td>16.7</td>
</tr>
<tr>
<td>Minimum</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Maximum</td>
<td>25</td>
<td>150</td>
</tr>
<tr>
<td>Number of observations</td>
<td>66</td>
<td>203</td>
</tr>
</tbody>
</table>

Source: Analysis of data collected by Cahill (2006)

CAPIs Derived Using Service Areas Based on Distance

Figure 4 presents an illustration of a number of network-based service areas based on travel distance for Barna Wood. They show the geographic areas that are within the specified distances of the recreation site. Once estimated, the service areas can be used to calculate CAPIs for a site by counting the number of GeoDirectory residential locations within them. This process is illustrated in Figure 5 which shows the distribution of GeoDirectory buildings within a 5km service area of Barna. Estimating the number of buildings falling within this area is a straightforward procedure using a GIS.

Before considering the estimated CAPIs, it is worthwhile to consider the difference between a service area estimated on a network as described above, and a more basic service area based on Euclidean distance. Figure 5 presents a visual illustration of the difference. The map shows that the 5km service area based on Euclidean distance covers a much greater area than the network-based service area. It also confirms the contention of Brainard et al. (1997) who note, “a concentric ring approach [i.e. service areas based on Euclidean distance] is prone to the criticism that it assumes a road network of uniform density and quality in all directions”, which is clearly not the case in Figure 5.
Figure 4: 5km, 10km, 20km and 50km service areas for Barna Wood

Figure 5: Estimating CAPIs using service areas
The differences between network-based service areas and ones based on Euclidean distances are further highlighted in Figure 6, which presents a comparison of 5km service areas generated using the two approaches for the two sites. The distinction is important since many studies still routinely use Euclidean based measures for estimating proximity e.g. Roe et al. (2002). In the case of Barna Wood, which is situated in a more urban area with a higher road density, the estimated service area covers a greater area than for Renville, which is situated in an area with a less dense road network. Thus, service areas based on the road network directly address the impact that road densities, which generally differ between urban and rural areas for example, have on site accessibility and the resulting catchment areas and catchment populations.

Figure 6: 5km service areas for Barna Wood and Renville Forest Park compared to 5km service areas based on Euclidean distance

(a) Barna Wood  
(b) Renville Forest Park

Catchment area population indicators using network-derived service areas and service areas based on Euclidean distance are set out in Table 3. (The 50km service areas are not considered here or subsequently since almost all visitors to both recreation sites travel less than 20kms.) For Barna Wood, the number of residential locations within a 5km network-derived service area of the site is 12,201. The corresponding CAPIs using 10km and 20km service areas are 28,707 and 42,345 respectively. In all cases these CAPIs are significantly less than CAPIs estimated on the basis of Euclidean-distance. For Renville the 5km and 10km network-based CAPIs are significantly lower than for Barna, though there is little difference between the 20km estimates for
the two sites. The differences in CAPIs based on the smaller service areas reflect the lower road and population densities in the immediate vicinity of Renville.

Table 3: CAPIs using network-derived service areas and service areas based on Euclidean distance

<table>
<thead>
<tr>
<th>Service areas</th>
<th>Barna Wood Network-derived</th>
<th>Barna Wood Euclidean measures</th>
<th>Difference</th>
<th>Renville Forest Park Network-derived</th>
<th>Renville Forest Park Euclidean measures</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>5km</td>
<td>12,201</td>
<td>16,253</td>
<td>4,052</td>
<td>2,228</td>
<td>8,071</td>
<td>5,843</td>
</tr>
<tr>
<td>10km</td>
<td>28,707</td>
<td>33,351</td>
<td>4,644</td>
<td>6,722</td>
<td>34,662</td>
<td>27,940</td>
</tr>
<tr>
<td>20km</td>
<td>42,345</td>
<td>47,082</td>
<td>4,737</td>
<td>43,635</td>
<td>51,034</td>
<td>7,399</td>
</tr>
</tbody>
</table>

Source: Analysis of GeoDirectory data

Given these estimates the question then arises as to which are the most appropriate service areas and associated CAPIs for the two sites. One approach to estimating an appropriate catchment area might be to consider the distance within which a fixed proportion $x$ of total visits (or visitors) to a site originate. So for example in considering the total number of trips to a particular site, we might consider a reasonable catchment area as one within which roughly 95% of all trips originate. In this case a 5km service area for Barna might be considered appropriate (94.2% of trips reported in Cahill (2006) originated from within this service area), while a 10km service area for Renville might be considered appropriate (from which 96.8% of trips originate). Thus the resulting CAPI for Barna is 12,201 and 6,722 for Renville under these parameter assumptions. If on the other hand the service area is defined as the area from which 99% of trips originate then a 10km service areas is more appropriate for Barna (with a resulting CAPI of 28,707) and a 20km service area is more appropriate for Renville (with a resulting CAPI of 43,635). This highlights that different recreation sites can have different catchment areas, presumably on the basis of differences in the quality of facilities and amenities on offer. Differences in the availability of other substitute amenities and activities are also likely to have an impact.

The estimates in Table 3 highlight the importance of choosing the appropriate extent of the service area in calculating the catchment indicators. The two sets of catchment
areas give rise to very different absolute and relative catchment population indicators. The value of $x$ in these scenarios is obviously arbitrary and indeed in certain circumstances a much lower value might be deemed appropriate. Choosing $x$ is unfortunately an inexact science requiring judgement and caution to be exercised for the particular case at hand. Furthermore, the value of $x$ might be chosen on the basis of where all surveyed visitors originate their journey as opposed to the origin of total trips. Local knowledge, including the location of substitute or alternative sites, is also an important input in choosing the appropriate extent of the service area. A sensitivity analysis such as that presented in Table 3 is useful in showing how responsive the CAPI estimates are to changes in assumptions regarding the extent of the service area.

**CAPIs Derived Using Service Areas Based on Travel Time**

Network analysis may also be undertaken where the objective function considers the time taken in making a journey, as opposed to the distance travelled. Service areas in which the specified impedance is time are known as ‘isochrone surfaces’. According to Brainard et al. (1997) an isochrone “is a line of constant time usually measured from a point source or set of points” while an isochrone surface “is composed of areas that lie within a set range of time values.” Alternatively, an isochrone is a set of points with the property that a given process or trajectory will take the same length of time to complete, starting from any point in the isochrone. In considering isochrones for a recreation site we measure the set of points along the road network reachable from the site, within a given time. The isochrone surface area is thus the set of points within the isochrone and represents an alternative measure of a service area.

The key variable in estimating isochrones is travel speed, since the distance travelled along a route (and hence the point at which the isochrone lies on the network) is equal to the time travelled multiplied by the travel speed. In order to estimate travel time ($TT$) for a given journey, one approach would be to divide the total distance travelled by the average travel speed for the journey. But the average travel speed of a journey is likely to depend on a number of factors, including road class, time of day, traffic volumes and whether the journey is in an urban or rural area. A better approach might be to assign different average travel speeds to different road segments, based on the characteristics of that road segment. To this end the (homogenous) road network
depicted in previous maps is differentiated by road class, with the goal of assigning different average travel speeds to the different road classes.

The approach taken in estimating $TT$ for a journey is to first separate the journey route into a number of different road segments. The length of each road segment ($RL$) is divided by an assumed average travel speed ($ATS$), where $ATS$ is a function of road class (discussed below) and whether the road is located in an urban or rural area. Unfortunately, due to a lack of appropriate data, we cannot account in our approach for differences in travel speeds for journeys made at different times of the day. Thus we define

$$TT = \sum_{i=1}^{N} \frac{RL_i}{ATS_i},$$

where the quotient $\frac{RL_i}{ATS_i}$ gives the journey travel time along road segment $i$. Summing this for all $N$ road segments between the journey start point and journey end point gives an estimate for the total journey time $TT$. The challenge is determining the correct values for $ATS$.

Some limited information in relation to average travel speeds by class of road in Ireland is available. For example, Kalogirou and Foley (2006) assign an average travel speed of 110km/h for motorways outside urban areas and lower speeds of around 25km/h for inner city roads. Furthermore, the Automobile Association of Ireland (AAIreland) provide an online journey route planner for Ireland (www.aaroadwatch.ie/routes/), and assign different average travel speeds to different sections of road, dependent on road type, traffic volumes and other factors. Such a detailed exercise is however beyond the scope of this research. AAIreland caution that it is difficult to estimate average journey speeds by road type but did provide indicative road travel speed estimates suggesting an average of approximately 100km/h for motorways, 80km/h for national roads, 60 km/h for regional and local roads as well as various speed limits in towns and cities dependent on a number of factors.

In addition to this the National Roads Authority (NRA) publishes a survey of free travel speeds in Ireland i.e. speeds at which drivers choose to travel when unconstrained by either road geometry (e.g. sharp bends), weather conditions (e.g. rain) or traffic conditions (e.g. congestion). Estimates are provided for different road classes in both rural and urban areas. The NRA caution however that estimates of
average free speeds would considerably overestimate the average speed on the network, as constrained vehicles will, on average, travel at lower speeds. Nonetheless, the NRA’s free speed estimates can be considered as upper bounds on any assumptions made in relation to actual average travel speeds and were taken into account in formulating our working assumptions. Based on this review we assume the average travel speeds as presented in Table 4 in our analysis but acknowledge the uncertainty attached to them.

Table 4: Assumed travel speeds by road class (km/h)

<table>
<thead>
<tr>
<th>Road element</th>
<th>National speed limit</th>
<th>Assumed average travel speed – urban areas</th>
<th>Assumed average travel speed – rural areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>National primary/ national secondary</td>
<td>100</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Regional roads</td>
<td>80</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>Third class roads</td>
<td>80/60/50</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>Fourth class roads</td>
<td>80/60/50</td>
<td>40</td>
<td>50</td>
</tr>
</tbody>
</table>

Source: NRA (for national speed limits) and authors’ assumptions

Once average travel speeds have been assigned to the different elements of the road network as described, a route analysis may be carried out between two points on the network in order to achieve the optimal journey route in terms of minimising journey time. This is in contrast to the example presented earlier, where the objective function involved minimising travel distance. In cases where travel speeds are likely to vary across road elements, the better indicator of the optimal route for an individual is likely to be the one which minimises journey time. Furthermore, the service areas presented previously representing the travel distance via the road network from a particular point may also be calculated in terms of journey times. As an example, Figure 7 presents 15min, 30min and 45min isochrone surfaces for Barna Wood, using the assumed travel speeds in Table 4.
Given the uncertainty regarding the average travel speeds along difference classes of the road network in County Galway, it is also useful to consider the estimated isochrones under different travel speed assumptions, such as those in Table 5. For all road classes these are slower than the assumed speeds in Table 4. Due to a lack of appropriate data on average road travel speeds for Ireland, it is unfortunately not possible to assert which set of assumptions is the more relevant. The benefit of using the two different sets of assumptions is that it provides a sensitivity-analysis of the estimates.

Table 5: Alternative assumed travel speeds by road class (km/h)

<table>
<thead>
<tr>
<th>Road element</th>
<th>National speed limit</th>
<th>Assumed average travel speed – urban areas</th>
<th>Assumed average travel speed – rural areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>National primary/ national secondary</td>
<td>100</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>Regional roads</td>
<td>80</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>Third class roads</td>
<td>80/60/50</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>Fourth class roads</td>
<td>80/60/50</td>
<td>30</td>
<td>40</td>
</tr>
</tbody>
</table>

Source: NRA (for national speed limits) and authors’ assumptions
Given the two sets of travel speed assumptions and their associated isochrone surfaces, estimated CAPIs are presented in Table 6 for both sites. In all cases the faster travel speeds yield higher CAPIs which is to be expected. The analysis shows the importance of the travel speed assumptions and the sensitivity of the absolute and relative estimated CAPIs to them. Using the original assumptions Table 6 suggests that there are almost twice as many residences within a 15min service area of Barna than Renville, while under the Table 5 assumptions the difference is closer to three-fold. Given the uncertainty associated with the average speed assumptions we do not comment further on the Table 6 estimates.

Table 6: CAPIs estimated using isochrone surfaces under different travel speed assumptions

<table>
<thead>
<tr>
<th>Service areas</th>
<th>Barna Wood</th>
<th>Renville Forest Park</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Under Table 4 assumptions</td>
<td>Under Table 5 assumptions</td>
</tr>
<tr>
<td>15min</td>
<td>29,945</td>
<td>22,707</td>
</tr>
<tr>
<td>30min</td>
<td>48,985</td>
<td>42,623</td>
</tr>
<tr>
<td>45min</td>
<td>71,321</td>
<td>56,394</td>
</tr>
</tbody>
</table>

Source: Analysis of GeoDirectory data

Concluding Remarks

In recreation demand modelling it is often not possible to accurately estimate the total population of users for a particular amenity such as a forest park. Consequently this paper proposes an approach to estimating catchment area population indicators for outdoor recreation sites using GIS-based network analysis and GeoDirectory. We believe that the methods presented allow the researcher to better estimate the catchment for a particular recreation site using travel information for a sample of visitors within a GIS framework.

We also believe that CAPIs may represent useful inputs for planning the location of recreation and leisure facilities as well as for resource allocation decisions across sites. For example, our approach can be used to estimate CAPIs for a proposed...
recreation site by estimating its likely catchment area (perhaps on the basis of a service area estimated for a similar site) and calculating the number of residences within the catchment area. Such estimates would help in determining the potential benefits of investing in potential sites since, as highlighted, the number of visits to recreation sites is a function of the distances that visitors must travel. Furthermore, the approach can also be used to consider the catchment population of other types of resources or facilities, though it is our opinion that the approach is most suited to circumstances where the catchment area is at a local as opposed to a national level.

Within this context it is important however to note the importance of choosing the appropriate extent or size of any estimated service areas for deriving useful CAPIs. As discussed this is not an exact science and we have shown in our illustrative example that service areas of different extents can give rise to very different absolute and relative catchment population indicators. Thus, reliable information relating to the distances and times that people travel to specific recreation sites is of crucial importance in determining this key parameter. Our analysis also shows that different sites can have catchment areas of different sizes. This is not surprising since sites providing better facilities will on average be expected to attract visitors from further away than sites of a lesser quality. This implies a more extensive catchment area for the former and a greater catchment population, all else being equal. Of course the estimated catchment population will be a function of the extent of catchment area as well as the numbers residing within it.

We also show in this paper that road density is a significant determinant of the size of a catchment area, though this is not always taken into account is assessing proximity. Finally, we find that caution needs to be exercised with respect to travel speed assumptions while estimating isochrone surfaces and that estimated CAPIs are sensitive to changes in these assumptions.

A number of important caveats to the analysis should be highlighted however. As presented the current approach to estimating CAPIs can only model the number of residential locations in the vicinity of a site or facility as opposed to actual populations of individuals. This is because GeoDirectory does not contain data in relation to the numbers of individuals resident in each building. In many cases
planning or investment decisions might require more precise data on the numbers of individuals residing close by, although the number of residential buildings may provide a useful proxy in some circumstances. Furthermore, data on the socio-demographic characteristics of the catchment populations might also be deemed important. For example the demand for different types of recreation activities also depends on individual’s personal and socio-economic characteristics and our approach does not currently account for this. There is also a concern in relation to residential buildings that may be vacant but not identified as such in GeoDirectory. Ongoing work which allocates simulated households from a spatial microsimulation model for Ireland to GeoDirectory residential buildings using statistical matching techniques seeks to address these issues. We also acknowledge the difficulty involved in choosing the appropriate size of service areas for calculating CAPIs. Finally, the approach does not currently account for differences in site quality and substitute availability. Such factors are likely to affect demand across different sites and thus also need to be considered.

References


**Notes**

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i A GIS is a computer program for creating, storing, analyzing and managing spatial data and associated attributes.

ii Geographic coordinates for Ireland are available in both the Irish Grid and Irish Transverse Mercator (ITM) reference systems. Geocodes are defined as references on the National Grid and ITM Grid that identify a particular place on the earth. Using these codes from GeoDirectory, in association with mapping and GIS software, facilitates accurately identifying the location of individual buildings.

iii A network is defined as an interconnected set of lines and points representing geographic features through which resources can move. Networks can be ‘directed’, in which flows along the network travel in one direction only (e.g. river systems), or ‘undirected’, where resources make their own travel decision (e.g. traffic systems).

iv *ArcGIS* is the name of a group of geographic information system software product lines produced by ESRI.

v Vector data consists of a series of nodes stored as (x,y) co-ordinates that define line segments. These line segments, when joined, form map features such as roads, buildings and rivers. Raster data on the other hand provides a map image formed by a matrix of pixels arranged in rows and columns, which can be displayed on a computer screen.

vi The Department of Health, Social Services and Public Safety publish average travel speeds by road class for Northern Ireland and were also considered in deriving the assumptions. Due caution was given however in relation to the applicability of using estimated road travel speeds from another jurisdiction primarily on the basis of the many differences in road transport infrastructure between Northern Ireland and the Republic of Ireland.