Transferring Multivariate Benefit Functions Using Geographical Information Systems

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SUMMARY

Recreation value studies have to date generally failed to adequately transfer functions predicting visitor numbers and benefit values from ‘source’ to ‘target’ recreational sites. One reason behind such failure may lie in the difficulty of successfully modelling the inter-site variation in predictors. The present study employs a geographical information system (GIS) to tackle this issue by integrating data from a number of sources (including a recreational site survey, the national census, regional road networks, etc.) permitting improved and standardised measurement and analysis of predictors at both source and target sites.

The paper applies Poisson regression techniques to a set of GIS derived explanatory variables predicting arrivals and consumer surplus estimates at a single target woodland recreation site. GIS techniques are then used to define a corresponding set of predictors at 30 other target woodland recreation sites across England for which actual arrivals numbers were known. Comparison of actual versus predicted arrivals provided a test of transferral validity which proved satisfactory and consumer surplus estimates were derived as before.

Key Words: Benefit transfers, GIS, Monetary evaluation, Woodland recreation.

JEL: C14, C42, H41

Abstract

The present decade has seen a growing interest in methods for the transferral of both benefit estimates and complete demand functions between open access recreation sites. This interest has been fuelled by the relatively high cost within such assessments of conducting individual valuation surveys at multiple sites. Research methods have moved swiftly in response to this demand, with initial studies examining values-only transfers being recently supplemented by attempts to transfer entire benefit functions. However, even these relatively sophisticated studies have (as their authors acknowledge) failed to yield reliable results (see for example Loomis et al., 1995). One reason behind such failure may lie in the difficulty of successfully modelling the inter-site variation in factors such as: travel cost (including adjustment of underlying journey times and expenditure for road availability and quality); population distribution and socio-economic characteristics; site quality; and the access to substitutes. The present study employs a geographical information system (GIS) to tackle this issue by integrating data from a number of sources (including a recreational site survey, the national census, regional road networks, etc.) permitting improved analysis of these factors.

A GIS holds map data in digital form, facilitating the derivation of appropriate variables for the entire extent of the case study area (all of England). Thus, for example the accessibility of any identified site can be measured from all feasible outset locations. Similarly, it is possible to estimate accessibility to all other destinations, thus permitting the calculation of a substitute availability index (which can then be weighted by time or distance as desired).

The paper presents an initial analysis of a surveyed ‘base’ site through which a readily generalisable methodology is developed for subsequent benefits transfer application to other ‘target’ sites. Analysis of the data provided at the base site through both an on-site survey and the GIS information gathered from our GIS analysis permitted the identification of comparatively homogeneous zones around the base site within which the values of each explanatory variable were constrained within user defined limits. Poisson regression techniques were applied in a stepwise procedure to assess the influence of each determinate upon predicted visits and travel cost measures of consumer surplus calculated.

The transferability of the resultant model was tested through application to a set of over 30 sites across England for which actual arrivals numbers were known. Comparison of actual versus predicted arrivals provided a test of transferral validity which proved satisfactory. The model provides sensitivity to a range of explanatory variables considered (including accessibility, demographic, site quality and substitute availability variables), thus constituting an improvement over the literature to date. Consumer surplus estimates were derived as before.

An extension to this work is also presented showing how the resultant valuation functions can be used to yield benefit transfer valuation maps. These describe the marginal value of creating a new site of a given quality in a variety of alternative locations. Such values can readily be compared with maps illustrating other woodland values (Bateman and Lovett, 1998), thus permitting cost benefit analysis of potential land use change. The paper concludes by highlighting some caveats to the use of GIS and consideration of future directions for research.

1. Introduction

Smith (1993, p.7) defines benefit transfer as the process of "adapting existing models or value estimates to construct valuations for resources that are different in type or location from the one originally studied". As McConnell (1992, p.695) indicates, "This is an attractive procedure because it saves time and money on repeated studies. There are many forces which are likely to increase the demand for non-market benefit estimates over the next few years. And with the growth in demand for benefit estimates, the issues of transfer methods will increase". Given these advantages, a consideration of the possibilities (and problems) associated with benefit transfer techniques is timely.

Many benefit transfer studies concern the evaluation of open-access recreational sites. To fully predict the recreational benefits of implementing a particular recreation policy (e.g. extending an existing woodland) at a site we ideally need three pieces of information: (i) the value of a visit; (ii) the number of visits made; and (iii) how (i) and (ii) will alter with changes in the quantity and quality of site characteristics. To date many studies have confined themselves to element (i) in an attempt to estimate a transferable value of recreational visits (Boyle and Bergstrom, 1992; Boyle *et al.*, 1994; Desvousges *et al.*, 1992; Luken *et al.*, 1992; and most notably Walsh *et al.*, 1989, 1992 and Smith and Kaoru, 1990). These studies have generally used statistical meta-analysis techniques to relate estimates from the existing literature to the characteristics of the sites under investigation. However, incompatibilities between the base studies on which such meta-analyses are conducted mean that their findings must be treated with considerable caution. As Smith and Kaoru (1990) note, at present these meta-analyses can at best only be used as consistency checks upon full benefit transfer studies.

Within the area of evaluating open-access recreation benefits, and following the work of Loomis (1992), there has been a recent move away from meta-analysis towards studies in which specific transferable demand functions are estimated from data derived from one or more 'base' sites. These functions are then applied to the 'target' sites for which benefits estimates are required with the values of explanatory variables being those that apply to the target sites.

Several transferable demand function applications have adopted variants of the basic travel cost model (Clawson and Knetsch, 1966). Equation (1) details a basic model linking the number of visits to a site with the time and distance cost of those visits (thereby allowing the estimation of visit values), and other predictors including the type and quality of facilities at the target site, the availability and quality of substitutes, socio-economic and possibly cultural factors, and other explanatory variables.

$$\begin{array}{llllll}
\text{VISITS} & = f\ (\text{PRICE}, & \text{SOCIO ECON}, & \text{SUBS}, & \text{FACILITIES}, & X\ ) \\
\uparrow & \uparrow & \uparrow & \uparrow & \uparrow & \uparrow \\
\text{No. of visits to} & \text{Cost of a visit in} & \text{Socio-economic} & \text{Type,} & \text{Type and} & \text{A matrix} \\
\text{the site under} & \text{terms of travel} & \text{factors (e.g. car} & \text{availability} & \text{quality of} & \text{of other} \\
\text{consideration.} & \text{expenditure and} & \text{ownership,} & \text{and quality} & \text{facilities} & \text{explanatory} \\
\text{Often expressed} & \text{time} & \text{unemployment,} & \text{of substitute} & \text{provided at} & \text{variables} \\
\text{as a visitor rate} & & \text{etc.)} & \text{sites} & \text{the site under} & \\
\text{(e.g. per} & & & & \text{consideration} & \\
\text{household pa.)} & & & & &
\end{array} \tag{1}$$

Despite the theoretical robustness of the Loomis (1992) approach, attempts to use a travel cost model in benefit transfer have not been particularly successful (see Parsons and Kealy, 1994; Loomis *et al.*, 1995; Adamowicz *et al.*, 1997). In previous work we have argued that many travel cost applications suffer from the rather poor accuracy and availability of the underlying geographical data used and the consequent strong assumptions adopted to overcome this (Bateman et al., 1996; 1997 and forthcoming). In essence we feel that the failure of travel cost based benefit transfer studies may not be because of inherent theoretical problems but rather due to more mundane, but in practice equally important, operational problems.

Our approach has been to tackle this problem through the use of geographical information systems (GIS); software packages specifically designed to handle and process spatially referenced data. This has allowed us to access, in a consistent manner, a far greater variety of data than have previously been used in benefit transfer studies; data which have national level consistency and provide a wide variety of the explanatory variables specified in Equation (1). The GIS also offers the analyst a range of data manipulation possibilities that would be impractical through conventional purely econometric routines, thus substantially enhancing the realism of visitation modelling.

This paper sets out to apply a travel cost based approach to benefits function transfer using a GIS-based methodology. The study is motivated through an analysis of the benefits associated with open-access woodland recreation, an area which has been a focus of extensive evaluation research in the UK (see Willis and Benson, 1989; Willis and Garrod, 1992; Benson and Willis, 1993; Hanley and Ruffell, 1993; Bateman and Langford, 1997; Forestry Commission and Countryside Commission, 1997). It is also of particular current interest given recent changes in UK agro-environmental policy (Department of the Environment, 1995; Countryside Commission and Forestry Commission, 1996) promoting widespread increases in woodland area across England.

GIS techniques are used to formulate a consistent and automated approach to the definition of visitor origin zones within which the values of the explanatory variables of Equation (1) are relatively constant (i.e. travel cost to the site, socio-economic characteristics, and substitute availability are roughly the same within each zone). Data on relevant variables are compiled for each zone and regressed, using Poisson regression methods, upon zonal visitation data to obtain an initial demand model (which proved a good predictor of visits to the base site). We then wished to transfer this function to about 30 target woodland sites across England for which Forestry Commission estimates of actual arrival numbers were available.

In order to transfer our demand function from the base to the target sites we first applied our GIS-based zonal definition routine to each target site in turn. Following this, site-specific values for each of the explanatory variables in the demand function could be derived and an estimate of visitor numbers and values obtained. However, one problem with this operation is that, because we are transferring from just a single site, we have no variation in terms of the facilities available at the various target sites. Therefore, a survey of facilities at all target sites was undertaken. This had low resource costs in terms of both time and expense and so was not considered to invalidate the central policy objective of benefits transfer, namely to obviate the need for expensive and lengthy visitor surveys at all target sites. Variables describing target site facilities were used to supplement predictions of the transferable demand function in modelling actual arrivals rates. As we did not carry out separate valuation exercises at target sites (because of resource limitations), the principal form of validation for this approach is a comparison of predicted against actual arrival numbers. We felt that this test would be appealing to decision-makers both for its simplicity and reliance upon readily observable arrivals numbers, rather than indirectly derived valuations.

Results from this exercise are reasonably encouraging and suggest that the advantages afforded by utilising the analytical capabilities of a GIS provide a substantial improvement to the prospects of successful benefits transfer.

2. Base Site Analysis: Data and Variable Definition.

2.1 Survey Data

The initial base site data for this study was a survey of 351 parties of visitors to Lynford Stag, a recreational woodland area within Thetford Forest in eastern England. Visitors were asked to provide a variety of information (see Bateman et al., 1996 for further details), but particularly their journey origin (given the zonal nature of this model, individual level data is not necessary for this analysis[1]) and whether they were on holiday or resident in the region. The journey origin placenames given by interviewees were subsequently related to one kilometre grid references, which were then matched to the census ward in which they fell for villages, or group of wards for towns[2]. From this sample we narrowed our analysis to 326 visitor parties (93% of the total) who travelled from within a 75 km radius of the site.

2.2. Calculating Travel Times

Road network details were obtained from the 1:250,000 Bartholomew digital database for the UK. Typical speeds for each class of road were extracted from Department of Transport sources (1992, 1993) and adjusted in a calibration exercise based on additional information as detailed in Bateman *et al.*, (1995). Driving times from every point on the road network to the study site were calculated, and these values rasterised onto a grid of 500 x 500 metre squares. To generate a travel time surface, empty cells (between roads) were filled by applying a weak distance decay function to imply slightly reduced access away from the network. This assumption has proved robust in our previous efforts to model travel times from this study site (Brainard *et al.*, 1997). The resultant travel time surface is illustrated in Figure 1.

A population layer for the study region was obtained by resampling 200 x 200 metre raster data available at Manchester University. This demographic information was generated using technical procedures discussed by Bracken and Martin (1989) to approximate the number of residents in regular grid cells from census centroid information. Combining the

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[1] This is a potentially important point in favour of our methodology, as the collection of such data alone would be much cheaper and easier than individual level survey information.

[2] One of the failings of this survey design was that home locations could have been gathered to an even finer accuracy. In a subsequent survey which is the subject of ongoing analysis, full postcode details were elicited giving an average origin resolution of about 100 metres. This should ensure more accurate extraction of zonal

population and travel time surfaces enabled the generation of population-weighted travel times from each ward or ward grouping to the study site. Comparisons between the travel times stated by visitors and those calculated by the GIS showed no significant discrepancies (Bateman *et al.*, 1996)[3].

2.3. Socio-Economic Factors

Ten census measures, listed in Table 1, were extracted for each ward in the study region[4]. These included two population measures (resident population and population density[5]) and two age variables (percentage persons retired and percentage aged five to nine years). There were no income questions in the 1991 UK Census, but various surrogate measures were extracted (percentage home ownership, households renting from the local authority (i.e. council housing), male unemployment and households lacking a car) and education was represented by the percentage of persons obtaining higher university degrees. We also experimented with combined male-female unemployment rates, percentage children aged five to fourteen and the rates of all university level qualifications, without substantial differences from the results described here.

2.4. Substitute Sites

While virtually all Forestry Commission woodlands are open to the public, access to privately owned woodlands is often either not allowed or by informal consent. This makes the definition of any accessibility variable problematic due to the lack of information concerning visits to private woodlands. Consequently it was decided to define two alternative accessibility measures, the first 'strict' measure relying mainly upon survey data from the Countryside and Forestry Commissions which identified sites that were definitely were used for recreation. A second 'broad' measure combined this data with further information concerning the geographical location of all woodlands[6] (for further details see Lovett *et al.*, 1997). Maps of the strict and broad definition of recreational woodland locations were

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socio-economic and related data.

[3] Further analysis of the relationship between visitor rates and travel time is presented in Bateman *et al.* (1998).

[4] Urban area measures were aggregated by calculating population-weighted averages of the ward statistics.

[5] Derived, by estimating the number of residents per 500 x 500 metre grid square in each ward or ward grouping.

[6] Specifically the broad measure also encompassed regions where two data sources indicated there was at least a moderate degree of tree cover. Ongoing work extends this research to examine the impact of non-woodland

converted into measures of substitute availability by first creating a regular 5km grid across the entire UK study area. For each grid point in turn, five-minute travel time zones were defined as detailed previously. Within each zone the total area of available woodland (according to each definition) was calculated. These were then weighted inversely according to the travel time from the grid point. The weight used was derived from our previous work on the travel time/visitation relationship (Brainard *et al.*, 1997) which suggested that the exponent for travel time when predicting visitors to woodland sites was around 1.65. Accordingly, the forest area totals in each time band were divided by the travel time raised to a power of 1.65, and the resulting scores multiplied by an arbitrary value of 1000 to make the range of values slightly more convenient to manipulate. These scores were summed across all time bands emanating from a given grid point origin to produce the broadly and strictly defined recreational woodland substitute availability index score for that grid point. The sample point values were subsequently interpolated and rasterised to produce data layers with values for the whole of the study area, hereafter referred to as WSTRICT and WBROAD. Figure 2 depicts the WSTRICT surface and the general trends in WBROAD were similar. Finally, both layers were combined with the population surface to generate population-weighted averages of the two substitute availability indices for each ward or ward grouping.

3. Base Site Analysis: Combining Travel Time, Socio-Economic and Substitute Availability Measures to Define Origin Zones

The geographical units in zonal travel cost models are typically defined using criteria of convenience and with little reference to model optimisation. Our approach to zone construction was influenced by the Poisson regression techniques that we wished to use. Such techniques are particularly suitable when the dependent variable (i.e. the number of visitor parties from a zone) consists of many small counts, but the Poisson assumption is less appropriate when values are very widely dispersed, or an excessive number of zeros are present (Lovett and Flowerdew, 1989). To reduce the incidence of zero values in this study, wards and urban groupings were combined together on the basis of similar attributes. Cluster analysis was applied to the various socio-economic and substitute availability measures to categorise the Lynford Stag catchment area into six socio-economic groups (illustrated in

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recreation alternatives.

Figure 3) and five substitutes categories (see Figure 4). The wards and urban groupings were also classified according to their travel time from the site into one of the following six categories: 0-15, 15-30, 30-45, 45-60, 60-90 and over 90 minutes travel time (illustrated in Figure 5). Given the established importance of journey time in travel cost modelling, it would have been desirable to distinguish more than six travel time categories, but it was necessary to have adequate resolution of the three main types of variables without too excessive a number of possible zones[7].

This approach led to the identification of 69 unique combinations of the travel time, socio-economic and substitutes categories, and these constituted our core origin zones (as illustrated in Figure 6). An important characteristic of these zones is that they were often made up of non-adjacent units; the boundaries of wards did not need to be contiguous for them to be grouped together. For each individual zone, population-weighted averages of the socio-economic, substitute availability and travel time variables were calculated so that numerical rather than categorical predictors could be used in the travel cost and benefit transfer models.

4. Base Site Analysis: Modelling Visitor Arrivals at Lynford Stag

Our initial attempts to predict visitor arrivals at Lynford Stag (see Lovett *et al.*, 1997) produced a model that was only just statistically significant at the 95% confidence level. That work used the same Thetford data in a somewhat cruder zoning system than the one described here. To improve upon it consideration was given to differences between holidaymakers and daytrippers (detailed in Brainard et al., 1998) and all socio-economic and substitutes variables were standardised and scaled so that each had a mean of zero and standard deviation of one. Expressing the variables in relative terms facilitated subsequent attempts to transfer the models to other regions (see subsequent sections), and it can be justified by *reference theory* (Runciman, 1966) which asserts that social measures are best considered in their relative context. For instance, socio-economic characteristics that suggest middle class status in one region may be interpreted as relative wealth or even poverty in a different area. Inasmuch as tastes and recreation preferences are shaped by social class identity (McAdams, 1992), it may be essential to consider social statistics in relative rather

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[7] Further details of the definition of unique origin zones is given in Lovett et al. (1997).

than absolute terms. With regard to the substitute availability variables, the argument for using them in a relative context is the possibility that supply excites demand. Individuals who have access to a number of recreational forests may make more woodland visits than they would if there were little provision nearby.

Equation (2) details the best fitting visitors function[8]. Significance testing in Poisson regression models is achieved by examining the scaled deviance value, which follows a Chi-square distribution. Residual deviance values below a specified threshold indicate that the hypothesis of no difference between the observed and predicted values cannot be rejected with a particular level of confidence (i.e. 95%). For Equation (2) the 95% critical deviance value was 81.37, whilst the residual deviance was 34.06, suggesting that this function provided a good description of the arrivals pattern.

$$\text{VISITORS} = \underset{(3.25)}{9.12} - \underset{(3.81)}{2.845} \ln \text{TT} + \underset{(3.47)}{0.618} \ln \text{P91} - \underset{(2.66)}{1.110} \ln \text{PDENS} - \underset{(2.19)}{0.242} \text{PMU}$$

$$+ \underset{(3.29)}{0.238} \text{HLC} - \underset{(2.45)}{3.095} \ln \text{WBROAD} \qquad (2)$$

Figures in brackets are t-statistics.

Residual deviance = 34.1 (95% critical deviance value = 81.37; model significant at = 5%)

where:

VISITORS = the number of holiday visitor parties from each zone to the site

TT = travel time in minutes

lnP91 = Natural logarithm of zonal resident population in 1991

ln PDENS= Natural logarithm of zonal population density (individiuals/km2)

PMU = Proportion of economically active males seeking work

HLC = Proportion of households lacking a car

WBROAD= broadly defined site specific substitute accessibility index

Examining Equation (2) we can see that arrivals were strongly determined by travel

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[8] This equation is based on observations of holiday visitors. Brainard et al., (1998) report a separate analysis for visitors setting out from home (i.e. day-trippers) for which the 95% threshold critical deviance was 77.92 and the residual deviance 57.5, a result that again indicates a satisfactorily fitting model. We do not discuss this model further here as, due to multicollinearity, only one model could be used as a basis for predicting visits to target sites in our subsequent benefit transfer analysis.

time and origin zone population both of which have the expected coefficient signs. The two socio-economic factors, PMU and HLC had differing signs suggesting a complex relationship, although concerns regarding the ecological fallacy (e.g. that a visitor from an area with a high HLC score may themselves own a car) may be pertinent here. The generally negative influence of population density may be due to the greater diversity of entertainment opportunities in towns and cities. As there tend to be more leisure options in urban areas, people vacationing there may be less likely to look to the countryside for their recreation. The negative relationship between visitation and substitute availability was as expected.

5. Consumer Surplus Calculations

Following general practice within travel cost studies unit vehicle operating costs (VOC) were defined to include all variable costs such as fuel and maintenance, but omitting fixed costs such as insurance and depreciation. However, while most travel cost studies assume a constant unit cost per km, work reported in Department of Transport (1996) suggests that actual travel behaviour reflects differing per kilometre costs for shorter as opposed to longer duration journeys. The latter report cites a number of alternative models for calculating perceived VOC, from which Equation (3) was derived for use within our study:

$$\text{VOC} = 2.35 * \text{KM} * (1.981 + 0.51804 * (\text{KM/MINUTES})^2\,) \qquad (3)$$

where:

KM = kilometres travelled

MINUTES = duration of journey in minutes

Consumer surplus was estimated as follows. Travel time was estimated using a wage rate approach (Cesario, 1976; Fletcher et al., 1990). The wage rate level was assessed through a conventional, individual TC study (reported in Bateman et al., 1996) wherein the percentage wage rate used to value travel time was allowed to vary so as to maximise the statistical fit of the model. This was achieved where wage rate was set at 2.5% of the median household wage of visitors. Applying this to the zonal travel time measures (as discussed in Section 2) provides a travel time cost measure for each zone. Zonal travel expenditures were calculated by applying Equation (3) to measures of travel time and travel distance (calculated using the approach discussed in Section 2). Summing zonal travel expenditure and travel time cost provided our estimate of travel cost for each zone. Regressing this against predicted zonal visitation (estimated from Equation (2)) provides a demand curve from which consumer surplus can be estimated via the simple Clawson-Knetsch (1966) approach of calculating the area under this curve for each zone. In the case of the Lynford Stag site, this approach gave an estimate of annual consumer surplus estimate of £80,239 which (given an estimate of approximately 42,000 party visits per annum) implies an average consumer surplus per party visit of £1.91. This estimate is consistent with the UK literature on woodland recreation values (for example, Benson and Willis (1992) report typical values ranging from £1.26 to £2.51).

6. Conducting Benefit Transfers Using GIS

In order to test the transferability of our estimated demand function, it was decided to apply this function to 33 English woodlands for which data were available regarding visitation numbers. The location of these sites is illustrated in Figure 7. Visitation data were obtained from two sources. A Forestry Commission (FC) document (Guest and Simpson, 1994) gave details of 1993 vehicle counts at several dozen locations across England. We assumed that each vehicle contained one visitor party. The Guest and Simpson information was supplemented by 1996 vehicle counter data provided to us by FC staff in Edinburgh. Because of the general view that the latter data were more reliable, where sites were duplicated in the two sources we adopted the 1996 value. Even given this adjustment, it must be emphasised that there are substantial uncertainties in the data. Guest and Simpson (1994) described numerous and in some cases ongoing problems in the operation of the counters. Our own analyses and assessments made by Willis and Benson (1989) suggest that, at very least, a minimum of 25 % error bands should be placed around these counts and the accuracy of predictions from the model presented below was therefore assessed against these bounds.

One of the problems of applying a demand function based upon observations from just one base site (here Lynford Stag) is that while there may be sufficient off-site variation in visitors to allow application to other target sites, no variations in on-site facilities are captured in the function. Ideally this would be addressed by deriving the transferable demand function from observations across a representative range of base sites (perhaps selected through cluster analysis as per Willis and Benson, 1989). However, resource limitations meant that such an approach was not possible within this study. Consequently, an alternative strategy was developed whereby a short on-site field survey of facilities at target sites was used to provide supplementary information to allow for facility differences between the base and target sites. The extent to which site facility variations influence arrivals away from those predicted by Equation (2) was assessed by estimating a further model relating visitor counts at each target site to both predicted arrivals (from Equation (2)) and various target site facility variables.

Data detailing these facility variables was collected via a survey of the physical attributes of target sites conducted in the spring of 1997. It was felt that as such a visit entailed very low resource costs both in terms of time and expense, and that this did not compromise the objectives of benefit transfer (to estimate visitation and values without resort to expensive and time-consuming individual on-site surveys of site users). Details of 27 types of facility were obtained. These included 21 binary (0/1) measures, such as presence of bicycle hire, an information centre, or facilities for disabled persons. Six continuos variable items were also recorded, including distance to the nearest B-class or better road, car park capacity (in number of vehicles), parking charges, percentage of coniferous woodland and the total distance of marked walking trails. In addition to these target site facility variables, strictly and broadly defined substitute accessibility index measures for each target site were also generated (yielding the variables SITESUBS and SITESUBB respectively). These differ from the measures used in Equation (2) where substitute accessibility is measured from zonal outset origins. While there is some correlation between the outset origin and site origin measures, as the former are only indirectly represented in the transferability analysis (through the estimation of predicted arrivals derived from Equation (2)), this does not result in any significant statistical problems.

Equation (2) was transferred to each of the target woodlands as follows. A study area around each site was defined so as to include all 1991 Census wards within a distance of 75 km. Journey times across each site's catchment area were determined using an updated (to 1996) road network and resulting travel time surface. The ten census measures in Table 1 were policy extracted or calculated for each ward. Outset origin substitute accessibility index surfaces were also derived for each catchment area. Population weighting was subsequently used to determine typical travel times and substitute accessibility index values for each ward. As described for Lynford Stag, the socio-economic and substitute accessibility variables were standardised so as to have means of zero and standard deviations of one. Next, cluster analysis techniques were used to generate socio-economic and substitute accessibility index maps with six and five classes respectively. Travel times were categorised into the same six groups as used in the Lynford Stag analysis. Wards sharing the same socio-economic, substitute and travel time categories were then combined to produce unique sets of internally homogenous outset origin zones around each of the target woodland sites.

For each zone, the value of each explanatory variable used in Equation (2) was calculated as before (i.e. TT, P91, PDENS, PMU, HLC, WBROAD). These variables were then transformed as per Equation (2) (i.e. natural logarithms of TT, P91, PDENS, and WBROAD were taken) and their value multiplied by their estimated coefficient (e.g. the value of lnTT was multiplied by -2.845). These values were then summed to give the Equation (2) prediction for that zone. This procedure was then repeated for all zones and resultant zonal visitor number estimates summed across all zones to give the total prediction of visits to the target site derived from Equation (2) (denoted EQ2PRED).

The estimate given by the variable EQ2PRED ignores any on-site characteristics which differentiate the target site from that of Lynford Stag. Such sensitivity was provided by the on-site survey variables and the site-specific measures of substitute availability.

The explanatory variables in our benefit transfer function therefore consisted of arrivals predicted via Equation (2) and a number of site-specific measures. These variables were calculated for each of the 33 sites for which Forestry Commission arrivals estimates were available. These arrivals estimates themselves form the dependent variable (FCVIS) in our benefit transfer estimating equation, for which Equation (4) reports our best fitting function.

$$\begin{aligned} FCVIS = {} & \underset{(1.87)}{-38676} + \underset{(2.07)}{88.43}\,EQ2PRED + \underset{(3.23)}{3.136}\,SITESUBB - \underset{(3.73)}{0.0016}\,SITESUBS^2 \\ & + \underset{(2.96)}{30547}\,BIKEHIRE + \underset{(2.38)}{1498}\,WALKKM + \underset{(1.43)}{14314}\,NATPARK \end{aligned} \qquad (4)$$

Figures in parentheses are t values. R^2 (adj.) = 0.75

where:

EQ2PRED = prediction from Equation (2)

SITESUBB = broadly defined site specific substitute accessibility index

$SITESUBS^2$ = strictly defined site specific substitute accessibility index raised to square power

BIKEHIRE = binary variable (1=available at site)

WALKKM = total kilometres of walking trails

NATPARK = binary variable (1=site in national park)

Results from this exercise are detailed in Table 2. Here official estimates are compared with predictions derived from Equation (4) from which estimates of per party and per annum consumer surplus are obtained and detailed. Eighteen or 55 % of the predictions fall within 25% of official estimates, while another 4 (12 %) are within 50 % of the official count. Three sites, Bakethin, Bull Crag and Lewisburn yield negative arrivals predictions; however, two factors seem to explain this: (i) Limited dependent variable approaches (censoring negative values) could have been applied and this is now being considered in ongoing work; (ii) All three sites are contained within the same forest and it may be that their separate treatment was not optimal. Extending this latter point it should be noted that the forest in question is located in the remote Northumbria area of northern England which has very low population accessibility and relatively high substitute accessibility. The result may therefore be highlighting deficiencies in the ability of the model to estimate demand in an area. It is also worthwhile to observe that in absolute terms the differences between the few negative forecasts and actual arrivals do not tend to be great (i.e. these are sites which attract relatively few visitors). Omitting these three forests results in 60% of predictions being within 25% of recorded arrivals and 73% being within 50% of recorded arrivals.

Estimates of consumer surplus, both as total site and per-party benefits are also listed in Table 2. These have been calculated using the same procedure as described for the base site and generally accord with the findings of previous research. In particular, per-party consumer surplus values for smaller, less-visited sites are usually greater than those for busier places, a result which reflects both theoretical expectations and prior research (Willis and Benson, 1989). However, since larger woodlands receive many more total visits their aggregate benefits are still much greater than those for their smaller counterparts.

7. An Extension : Benefit Transfer Valuation Maps

Given the relatively satisfactory performance of the transferable demand function developed above it was felt that such a model could reasonably be used as a first approximation land use planning tool. One extension of this approach is to use the underlying models to produce maps of recreation values so as to highlight higher value locations for either the enhancement of existing sites or the provision of new sites.

Valuation maps can be readily generated using the GIS by first defining a regular grid of points across the planning area. Each grid intersection is treated in turn as if it is a woodland site. Our transferable demand function is then applied to each grid site by first calculating the travel cost, substitute availability, socio-economic and other map surfaces relevant to that site, then deciding which facilities would be provided at the site, and finally estimating predicted arrivals and consumer surplus as before.

It was decided to test out such a methodology on the entire area of Wales. Such a case study was chosen for three reasons: first, previous work (Bateman et al., forthcoming) using a simpler function (consisting of a single, travel cost, explanatory variable) had assembled much of the road network, population distribution and related data necessary for this extension; secondly, this earlier simple model had produced satisfactory results suggesting that our extended model should work well in Wales and; thirdly, the area had also been the subject of related work on the timber and carbon sequestration benefits and opportunity costs of woodland (Bateman, 1996; Bateman and Lovett, 1998) raising the possibility of incorporating recreation benefit transfer values within a wider cost-benefit analysis.

Given the large area under consideration it was decided to define grid sites at 5 km spacings. At each grid site in turn our methodology was applied as discussed above. Results from this analysis can be seen in Figure 8 which details predicted annual arrivals numbers at each grid site. Careful interpretation of this figure is important. These results assume the creation of a new site (or enhancement to the specified level of facilities of an existing site) located at the centre of each grid square. The substitute accessibility variable encompasses all other existing sites but ignores any other simultaneously created (or enhanced) site. Thus the map consists of strictly marginal values. It provides a defensible estimate of the arrivals to the new grid site but once such a site is created, the consequent change in substitute accessibility would negatively impact upon arrivals at any subsequently created site. Therefore the values in Figure 8 cannot be summed. Once one site is added (or enhanced) the empirical exercise would have to be repeated anew to generate a map accurately predicting arrivals (and values) at other sites. Nevertheless, given that decision-makers face the constraint of limited resources, these initial result maps are useful in that they indicate where arrivals (and values) will be highest.

We can contrast these estimates with those produced in an earlier analysis (Bateman et al., 1995) which did not incorporate substitute availability into the predictive model. Resulting arrivals estimates from this initial model are illustrated in Figure 9. Contrasting this with Figure 8 we can see that incorporation of substitute availability results in a substantial reduction in predicted arrivals at any given site; a result which conforms to prior expectations.

Consumer surplus per visit is calculated as before and multiplied by predicted arrivals (from our present model as detailed in Figure 8) to estimate the total annual consumer surplus per site measures illustrated in Figure 10.

The distribution of estimates in both Figures 8 and 10 is similar and reflects the sensitivity of our transferable demand function. Values are highest in two areas (i) the south east where, although substitute accessibility is reasonable there is a high local population (in Cardiff and Swansea) and very good road links to even larger populations in England (Bristol etc., which were incorporated within our transferable demand model) and (ii) the north east where substitute accessibility is low and there is high demand as a result of excellent road links to the large populations of nearby Liverpool and Manchester. Conversely values are lowest along the West coast, particularly in central areas where low local populations, relatively poor road infrastructure and high substitute availability conspire to substantially reduce predicted arrivals and consequent site total values.

Value maps such as that illustrated in Figure 10 can readily be compared with other monetary maps of timber and carbon sequestration values to permit estimation of a broader definition of total woodland benefits, from which maps of opportunity cost (here agricultural output forgone) can be subtracted to yield more accurate estimates of the net benefit of establishing new woodland sites. Examples of such analyses are given in Bateman (1996) and Bateman et al. (forthcoming).

8. Conclusions

This paper has presented an attempt to utilise the analytical capabilities of a GIS to address some of the complex issues hampering successful benefits transfer. We would highlight the potential for addressing several complex measurement issues (particularly regarding travel time and distance) facing TC based benefit transfer models, for incorporating in a sophisticated manner substitute accessibility variation across a large area, and the way in which zonal definition can become flexible yet systematic through application of GIS procedures.

The model produced works reasonably well and results compare favourably with other studies in this field. Furthermore, as the extension described in the preceding section illustrates, there is substantial potential for the integration of results within decision planning systems. Nevertheless, while our results are, we believe, defensible they are still far from perfect and prediction for any one given site is still fraught with substantial uncertainty[9]. There is, we believe, still a long way to go before benefit transfer techniques can reliably substitute for individual site surveys.

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[9] We are particularly concerned that our own work is based on data from just one base site and are currently addressing this via a multi-site survey.

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Table 1: Statistics extracted from the 1991 Census.

Variable	Acronym
Population measures:	
Resident population in 1991	P91
Population density (individuals/km2)	PDENS
Age measures:	
Population under 5 years	PU5
Population aged 5-9 years	P5T9
Retired persons	PRET
Earnings measures:	
Households owner-occupied	HOWN
Households renting from the local authority	HRENT
Households lacking a car	HLC
Economically active males seeking work	PMU
Education measure:	
Persons over age 18 with higher university degrees	HUEDU

Note: except for P91 and PDENS, all variables were expressed as percentage values with appropriate denominators.

Table 2: Official estimates and predictions from Equation (4) of arrivals at 33 English woodlands. Consumer surplus estimates are derived from our predictions of arrivals.

Site Name	**Official Count**	**Predicted Visits**	**Per-Party Benefits (£)**	**Calculated Consumer Benefits (£)**
Dunwich	18,980	__15,957**__	1.56	24,828
High Lodge	14,940	46,925 †	1.33	62,381
Lynford Arboretum	7,101	21,356 †	2.83	60,354
Lynford Stag	42,010	14,745 †	1.91	28,098
Two Mile Bottom	22,636	__22,678**__	2.72	61,676
Bakethin	5,379	-12,231 †	_NA_	_NA_
Bull Crag	9,533	-9,341 †	_NA_	_NA_
Kielder Castle	24,243	56,747	3.57	202,767
Forest Drive	31,641	__26,200**__	3.57	93,616
Lewisburn	8,746	-1,548 †	_NA_	_NA_
Warksburn	3,794	___5,351 *___	7.42	39,706
Bogle Crag	14,924	47,475	5.38	255,408
Grizedale	85,181	__81,015**__	3.48	281,824
Noble Knott	7,543	35,407	3.51	124,149
Whinlatter	55,797	__60,838**__	3.36	204,571
Blackwater	39,338	__37,518**__	5.19	147,813
Bolderwood	22,963	__28,503**__	4.86	182,318
Moors Valley	165,552	__157,561**__	4.14	652,149
Bucknell	21,360	45,526	1.63	74,117
Salcey	77,650	__75,644**__	2.23	168,735
Wakerley	51,490	__42,354**__	2.06	87,456
Dalby	130,151	___77,804 *___	3.31	257,260
Chopwell	42,298	___54,251 *___	6.36	344,846
Hamsterley	76,796	__71,770**__	3.50	251,462
Simonside	12,430	32,526	2.94	95,462
Blidworth Bottom	54,547	__41,844**__	3.15	131,776
Blidworth Lane	52,754	__45,103**__	3.16	142,394
Blidworth Tower	37,596	__45,288**__	2.91	131,660
Chambers Farm	23,605	__22,808**__	1.92	43,836
Goyt The Street	84,279	__73,400**__	2.63	193,058
Normans Hill	30,936	__35,975**__	2.66	95,748
Thieves Wood	72,276	___45,617 *___	2.66	121,474
Sherwood Centre	38,919	__42,325**__	1.78	75,430

__**Bold__	= predictions within 25% of official estimates
___*Bold italic___	= predictions within 50% of official estimates
†	= Subsites; sites within a larger forest with multiple sites

Figure 1: Estimated travel times to Lynford Stag (only East Anglian area illustrated)
(Source: Bateman et al., 1996)

Figure 2: Substitute availability measure WSTRICT for the East Anglian area.

Figure 3: Six socio-economic zones defined by cluster analysis

Figure 4: Five substitute availability classes.

Figure 5: Six travel time classes.

Figure 6: 69 unique origin zones defined for visitors to Lynford Stag (socio-economic, substitute availability and travel time variables are relatively constant within zones).

Figure 7: 33 English woodlands for which official estimates of visitor arrivals were available.

Figure 8: Predicted annual arrivals numbers at each grid site across Wales.

Figure 9: Predicted annual arrivals numbers at each grid site across Wales (initial model excluding substitute availability, from Bateman et al., 1995)

Figure 10: Estimated total annual consumer surplus per site across Wales.