Monitoring and Management of Visitor Flows in Recreational and Protected Areas
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GIS-based modeling of car-borne visits to Danish Forests

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Abstract: Vector-based GIS is used as a basic for building a predictive model of car-borne recreational activities in Danish nature areas. Special attention is paid to the forests. The model takes its point of departure from frequencies of forest visits considering type of starting point (dwelling, summer house etc.), travel cost (into four time-bands) and three different nature types (forest, beach, and the remainder landscape). By means of linear regression statistics the model results are correlated with registered activities (number of cars in an extensive selection of parking lots in the nature). Further the effect of various local amenities – distance to the coasts, terrain form etc. – are evaluated. The work is part of the authors Ph.D.-thesis (Skov-Petersen, 2002).

INTRODUCTION AND MOTIVATION

There is a rising request for information about the recreational usage of and pressure on the nature surrounding us. The reasons are numerous including, e.g. more focus on non-market products of forests, a turn in planning and management of the nature to take public participation more into account, and a higher pressure due to the population increase, the sprawl of urban areas, and rising tourism. From the producers side – the forest managers and operators – there is rising concern that wood-production only is not enough to motivate a continued political support, as land is getting scarcer or requested for other activities. As a response to - or a consequent of - this rising emphasis on the multipurpose function of the nature in general and forests in specific, planning and management of the nature needs tools. Further, planning, at least in the developed part of the world, is opening up. This also influences planning of natural recreational resources. Public participation and involvement of NGO's and planning authorities at different levels of planning is getting an integral part of management and planning of nature where it in earlier times was more a concern of few central institutions or land owners. In the process of planning and designing the future forests data and information are needed. This goes as well as a political decision support (Kock, 1975, p 7) and for planning (De Vries and Goossen, 2001).

The Danish forest area has to be almost doubled from approximately 12 % of the national territory to approximately 22 %. In the forest act of 1996 (Miljø- og Energiministeriet, 1996) it is stated that the afforestation must facilitate multipurpose use. Among the main motivations are mentioned protection of ground water reservoirs and facilitation of recreational opportunities to the public. It is the intention of the present paper to demonstrate means for evaluation of recreational potentials of existing as well as planned forests and other nature areas. A full description of the project will be found in Skov-Petersen (2002).

OVERVIEW OF THE METHOD

The present investigation is activity orientated. It is seeking to estimate the potential number of visitors to any Danish nature area (with most focus on forests). The empirical data used include both questionnaires (approximately 2500 responses) and registration of actual activities – in terms of parked car - at approximately 2200 locations in the landscape. Both data-sets were kindly made available to the project by Frank Søndergaard Jensen of the Danish Forest and Landscape Research Institute. Partly as a consequent of the available data only car-borne activities are taken into account. Therefore the estimated modelled number of visits to areas close to highly inhabited areas, where the proportion of non-car-borne activities are significantly higher than in the more scarcely populated areas must be interpreted and used accordingly.

The study has a strong emphasis on the structural component. The main emphasis is on the influence of distance between users and resources – in terms of the travel needed between the point of departure and the destination. It is less focused on the choice process e.g. in relation to socio-economic characteristics of the users. Neither is the attention to compile any kind of economic valuation of non-market products of the nature.

The methodological foundation is heavily GIS-orientated and is therefore limited to model approaches and data that can be implemented in a GIS-context. Travel distances are calculated be means of a digital road network. Each node of the network is attributed information about nature resources (beach, forest, and remainder landscape), and the number of users (population, summerhouses, camping lots, hotels and youth hostels). Transport time is sliced up into 4 bands (0-10, 10-20, 20-45, and 45-120 min.). Classes of resources, users, and transport time are in accordance with those used in the questionnaire survey which provide frequencies of travels made to unique combinations of classes (time vs. user-type vs. nature type). The modelled visit-frequency to each node of the network is compared to the actual number of cars registered by means of linear regression statistics. Further, the effect of local amenities (terrain form, closeness to the sea, etc.) is evaluated.

Eventually, the resulting model is used to evaluate a number of afforestation areas appointed by the Forest and Nature Agency. Additionally, using a 1000x1000 grid an assessment – covering the entire Danish territory - of the recreational effect of afforestation is performed.

MEASURING AND MODELLING RECREATIONAL BENEFIT

When it comes to the unit of model results, there seems to be two mainstreams: One that seek to *capitalise recreational benefits in monetary terms* and one that assess the *recreational activities in terms of behaviour*. The main reason that monetary units are strived for, is that it enables comparison of benefits of accessible natural resources with alternatives, possible costs, loss of production, etc. (See for instance Wilhjelmudvalget, 2001, Powe et al., 1997, or Handley and Ruffell, 1993). The monetary valuation of non-market aspects (including recreational use) ranges according to Handley and Ruffell (1993) from various assessments of the value of a day in the forest, values (both user and non-user) of welfare gains due to afforestation, and estimates of carbon fixing benefits. Additionally, Powe et al. (1997) provides an example of valuation of forest resources based on changes in market-prizes of real estate, as a function of proximity to woodland. Loomis (1994) addresses the effect of recreational activities on local/regional economics as an alternative monetary assessment of recreational values of the natural resources. Contrasting monetary valuation *behavioural or activity-based measures* of recreational values of the nature includes measures of the publics *preferences* for different types of nature, *choices* between alternatives, and finally how these preferences and choices are reflected in the *actual activities* taking.

Another main fault-line in the methods for assessing recreational values is the mode of measuring and accordingly, the following mode of analysis and interpreting. The most direct, in terms of address of user, the approach *of stated preference, behaviour, or Willingness To Pay (WTP)*. Individual people are asked about e.g. their actual behaviour (‘When did you last time visit the forest’, preference (‘Do you like this picture or that?’), or WTP (‘How much would you pay for…?’). Alternatively the recreational values can be obtained by registration of the actual activities taking place in the nature or locations related to it. R*evealed preference, activity, or WTP* as this type of study is referred to, can be carried out e.g. by counting the number of parked cars on parking lots, the number of hikes in an area, or by registration of changes in value of real estate as a function of provision of green resources. Some writers refer to the same two types of valuation as *direct vs. indirect registration* (Smith, 1989 and Wilhjelmudvalget 2001).

When assessing human interaction with its recreational surroundings the three basic components are attributes to the *origin*, *destination* and *the system enabling transport* between the two (see for instance Vickerman, 1974a). Origins can for instance be characterised by demography, socio-economy, land use etc. Destinations by the nature type, landscape form, availability of local facilities, entrance fees, etc. The most basic form of transport costs or impedance’s is the Euclidean distances between origins and destinations. This approximation involves two assumptions: a) homogeneity in the spatial distribution of the transport network and b) that possible travelling speed is even all over the network. As the advances in development of GIS has facilitated efficient and accurate calculation of distances and transport times in digital road networks the use of Euclidean distances has become less abundant. The pros and cons of Euclidean vs. network-distance calculation has been discussed in numerous articles including Brainard et al. (1999), de Vries and Goossen (2001), and Bhat and Bergstrom (1997). The effect of increasing distances - e.g. close things means more than more distant ones - or most frequently formulated in terms of 'distance-decay'. The simplest form is the sharp threshold or isocrone functions - anything within a given search radius is included with full effect, whereas all outside the radius are excluded. An example of a more gradual decay function is the 'gravity model' where - in its simplest form - effect is divided by the square of the distance. Distance decay functions, with special reference to recreational resources and behaviour are discussed by Skov-Petersen (2001). In cases where the model includes areas where no roads are available at present – either because a future, potential situation is addressed (Geertmann and Ritseman van Eck, 1995) or because the digital network used doesn’t include small roads and tracks in between main roads Euclidean distances can be used as a supplement to network analysis (Brainard, et al. 1999). Skov-Petersen (1998) provides an example of local Euclidean distances used in a raster-GIS environment for assessment of barrier effect of larger traffic constructions.

A special problem in modelling recreational choices is handling the influence of *alternative choices,* i.e. the effect of the amount of recreational resources available at a point of origin. It can be assumed that the number of visits from an origin to a destination is a function of the magnitude of the demand (e.g. the total number of forest visits), inversely related to the sum of the available resource (e.g. the total number of ha forest available within the time-constraints considered) (Smidt, 1989, Luzar and Hotvedt, 1992, Loomis, 1995). The same issue is sometimes referred to as *intervening opportunities* (Thompson, 1979).

ASSESSMENT OF THE METHODS USED FOR THE PRESENT STUDY

Of the above referred studies the present study resembles especially Brainard, et al. (1999) and de Vries and Goossen (2001). Both predecessors are using GIS as central platform for implementation, and both are highlighting the problems and possibilities in using a digital road network for assessment of travel costs. Further, both studies are aiming at development of a method that could facilitate estimation of recreational values in any nature area within a given region. As de Vries and Goossen (2001) this study is considering a dual data-set including a *stated preference assessment* ‘feeding’ a travel cost model and a *revealed behaviour study* of activities, registered directly on site in the nature. The motivation is the same; to validate the model in terms of correlation between modelled and registered activities and to enable evaluation of the effect of local facilities and amenities in the nature on recreational activities. Brainard, et al. (1999) argues that an economic valuation is needed to enable transfer of (economic) benefit between sites, whereas the present study wishes to evaluate the effect of landscape amenities on recreational activity. Brainard, et al. (1999) consider different types of origins – dwellings and summer houses – similar to the present study which additionally includes departures from camping sites, youth hostels, hotels, and holiday departures from private homes. Since Brainard, et al. (1999) are using information about the individual respondents origin as well as destination, they have the opportunity of evaluating effect of socio-economic characteristics of the zone of origin on choices and behaviour in terms of forest visits. The evaluation of socio-economic characteristics was given less priority in the present study. A general difference though, is the inclination of Brainard, et al. (1999) to value the nature in monetary terms, contrasting the present study’s search to model activities in terms of visits. The obvious spatial components in the phenomena of recreational benefit and behaviour seems not to give raise to much attention to the geographical aspects of the [economic] studies involved (Brainard, et al. 1999).

The basic motivation – to facilitate the planning process with knowledge regarding recreational aspect of the nature in terms of recreational activities – is shared between de Vries and Goossen (2001) and the present study as are a number of basic assumptions and approaches. Despite of this the two studies seems to deviate on three points: de Vries and Goossen (2001) addresses a) both car- and bicycle-born activities (the present study only includes cars), b) a gravity model is used (the present uses time bands), and c) a rather detailed conception of the quality of different nature types is included (the present study considers only beach, forest and the remaining landscape). Further, de Vries and Goossen (2001) have a high degree of details on differences in social groups living in different points of departure but, as a contrast to the present study, only departures of the dwelling population are considered. De Vries and Goossen (2001) makes no attempt to evaluate their model results in terms of real world registrations of actual levels of activity, which is included in the present study.

To summarise the present study is characterised by:

- The introduction of both revealed and stated preference information in the same model
- Even though calculation of travel cost is considered central, it is kept in terms of transport time - not in monetary terms.
- Points of departure are disaggregated into residential houses, summer houses, hotels, camping lots, and youth hostels not only on population being only an indicator of departure from residents.
- Travel cost is treated as probabilities of activity in time bands (not as a monotonous distance-decay)
- Division of the number of users at an origin by the total area resource within the considered time-band as a means for treatment of intervening opportunities or surrogate destinations
- Finally an address is made of the way the size of destination regions is influencing the correlation between model results, local amenities, and actual, registered visitors.

OVERVIEW OF THE METHOD AND DATA BACKGROUND

The following section describes the data-background, the pre-processing of data. Later the steps of the accessibility modelling process are described. The pre-process includes a) extraction of data from interview survey, b) digitising ‘car-registration points’, c) filtering the road-network, d) calculation of transport-time for each road-segment, e) calculation of population-data, and f) aggregation of user- and resource information to the nodes of the road-network.

Five types of data are used for the analysis:

- A *national* set of information about the stated preferences and behaviour of the general population
- The number of cars registered at a number of parking lots in the landscape during 1995
- L*ocal* data-sets about resources (forests, beaches and remaining untilled landscape.
- A *local* data-set of the number of potential users (population, summer houses, capacity of hotels, youth hostels and camping lots).
- Information about the *transport-network* (describe data background and attributes, filtering, spatial aggregation).

National data refers to non-spatial information being general for the entire area under investigation - the country of Denmark. Local data is geographically disaggregated information, information that differs from one location to another. The distinction between local and global information is made to highlight the difference in nature of the two data-types. The national information serves as 'constants' that can be used for calibration of local information, which can be used for the modelling of spatial interaction.

The modelling processing included a) calculation of the yearly number of trips generated by each combination of time, means of transport, nature-type and type of point of departure (from the questionnaire survey), b) calculation of the amount of resource available at each origin, c) calculation of the number of trips generated at each origin, d) calculation of the number of trips made to each destination, and finally e) comparing calculated number of trips and the number of cars actually counted in the nature.

CORRELATION OF NUMBER OF COUNTED CARS AND ESTIMATED TRIPS

Registration of cars took place 22 times during 12 month in 1995-96. The registration was made at parking lots or along stretches of road known or expected to be used during recreational visits in the nature. The nature areas was enrolled voluntarily by the administrators and registration locations was configured to cover entire nature areas, i.e. it was expected that all cars coming to an area during the time span of a single round of registration would be included. To relate the registration-point to the landscape surrounding them, buffer zones had to be introduced. In some cases – depending on the buffer-size and the spatial distribution of the registration-points – the buffer zones would embrace more than one registration points. This way a single buffer-zone containing a number of registration-points and a series of landscape attributes becomes the minimum unit of investigation

A key point is the selection of a feasible size of the buffer-zones. The buffers should be big enough to even out local variation, both in terms of different attributes to the individual parking lots that might influence the number of visitors and in terms of the data background used for estimation of trips and local attraction parameters (see below). On the other hand they should be small enough still to support estimation of recreational use at a local scale. If only correlation's can be established for large regions it would disable the evaluation of natural areas smaller than the regions. Further, using too big buffers would in cases include natural areas not included in the car-registration campaign. Whichever buffer-size is selected it must also be considered in the context of the behavioural phenomena investigated. The buffer should represent the landscape in a vicinity of the registration point relevant to the activity considered. If a too small buffer is selected, the activity will stray outside it – or is it a too big buffer it will include areas of no relevance to the recreational activity. To unwrap the influence of buffers size a number of different sizes – 125, 250, 500, 1000, and 2000 m - were tested.

The problems associated with aggregation of data into area units – with special reference to the inferential effects of changing aggregation units - are generally referred to as the Modifiable Area Unit Problem or its abbreviation MAUP (Oppenshaw, 1980). Very different correlation's between the same set of variables can be obtained by using different aggregation units. The phenomena can be separated into *a scale effect and an aggregation effect*. The scale effect includes in general that the larger the aggregation units, the larger the correlation between the variables investigated. The aggregation effect occur when a constant number of aggregation areas are moved, reshaped, and resized over an area of investigation. According to Oppenshaw (1980) the optimal or most correct correlation coefficients can in principle be obtained by introduction of all possible configurations of aggregation areas and the examine the frequency distribution of the resulting coefficients. The present approach of using multiple buffers gives the opportunity to investigate the stability of estimates over changing scales in aggregation units. In this way the effect of MAUP – specially the scale effect – can be assessed and envisaged.

At the destinations the natural resources are only considered as belonging to one of he three broad classes; beach, forest, and the remaining untilled landscape. It can be seen as a background pressure of potential visits. Obviously, despite of this background pressure, number of visits varies very much even between sites situated very close to each other. Therefore a number of parameters representing local attraction of the nature were introduced as additional descriptive and/or explanatory variables. These variables include ruggedness of the landscape, closeness to the coast, closeness to lakes, and closeness to locations marked as especially scenic or picturesque.

STATISTICS

A central question if the model performs any better as a predictor of the recreational activity in the nature than the classical models entirely driven by population potential (See for instance. Skov-Petersen, 2001). To assess this expectation of explanatory effect correlations coefficients of the number of cars and the predicted values was calculated. As can be seen in 0 the two classical models (model 2 (exponential distance decay function) and 3 (isocrone distance decay (15 min.))) do not provide any marked explanation of the recreational activities in the areas encounter. Further there is no effect of increase in the buffer size. For the full model (model 1) the picture is more positive there is a marked increase in the correlation coefficients as a function of increasing buffer size.

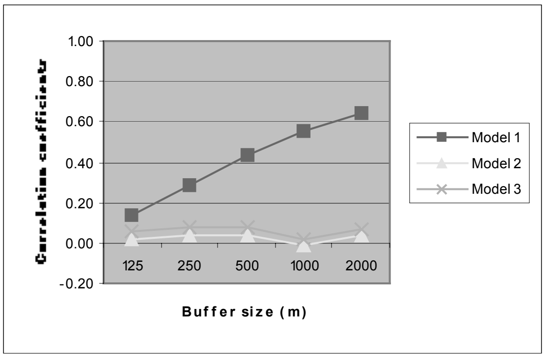

Figure 1: Pearson correlation coefficients of the three models vs. counted number of cars as a function of rising buffer size. Figures are based on the logarithm of counts and model results.

From 0 it can be seen that the number of trips modelled by *accessibility, distance to the coast*, and *slope index* all provides significant estimates of the regression coefficients. All three appears to be robust – in terms of the sign of the estimate vs. increasing buffer size. Accessibility and slope are both positively correlated – i.e. the higher prediction of the accessibility-model and the more slope the landscape, the higher is the recreational activity. Distance to the coast is negatively correlated – the further to the coast the lower the activity. The correlation with the distance to the coast might be an influenced by the high number of registered activities at parking lots facilitating the beaches.

Buffer size (m)	Accessibility (Model 1)	Distance (m) to coast	Slope index
125	0,420720 (0.0001)	-0,000014 (0.0012)	0,435067 (0.0001)
250	0,466505 (0.0001)	-0,000027 (0.0001)	0,289057 (0.0001)
500	0,519789 (0.0001)	-0,000037 (0.0001)	0,276821 (0.0001)
1000	0,603275 (0.0001)	-0,000033 (0.0001)	0,305682 (0.0001)
2000	0,571046 (0.0001)	-0,000037 (0.0001)	0,172477 (0.0962)

Figure 2: Estimates of regression coefficients for parameters selected by stepwise linear regression vs. buffer size. Level of significance mentioned in brackets. Estimates of significance lower than 0.1500 are excluded.

USING THE MODEL FOR ASSESSMENT OF RECREATIONAL EFFECT OF AFFORESTATION

The following two sections provides two implementations of the estimated regression coefficient's of the accessibility model (based on population, summer houses, hotels etc. and existing recreational resources) and local amenities (distance to the coast and terrain form) as independent variables and the expected number of car-borne visits to existing and potential afforestation areas as dependent variable.

When interpreting the data it is important to bear in mind that the estimates represents car-borne activities only. Generally car/motorcycle born activities takes up 46.3 % of the entire national recreational activities but the proportion of other, softer forms of traffic increases when the transport distances decreases (Jensen, 1998, pp 46). E.g. at less than one kilometre approximately only 10 % of the participants are using the car. This means that the closer the fringes of the inhabited areas the less significant is the car-borne activities when compared to other means of transport. With special reference to the present model this is in particular true when the case is rims of small towns. No-one in these cases can travel long distances to go to an area close to the rim. In the cases of larger cities the population of the centre of the city are potentially 'long-distance users' of the recreational areas at the rim. Accordingly, care must be taken not the neglect the potential effect of non-car-borne activities, especially in the case of close-range travel distances.

EVALUATION OF STATE AFFORESTATION AREAS

The Danish Nature and Forest Agency has appointed a number of areas of special action in terms of afforestation. A digital map of 95 of these areas were made available to the project. As an example for the results for the County of Funen are found in figure 3 (index map found in figure 4).

Index number	Project name	Area (ha)	Lower confidence interval (95 %)	Predicted number of yearly visits by car	Upper confidence interval (95 %)
19	Højstrup	283	2165	2763	3526
20	Kerteminde	388	1307	1760	2369
21	Middelfart	1088	2697	3547	4664
22	Årslev	146	713	868	1055
23	Ejby	148	458	592	765
24	Gelsted	26	95	138	197
25	Kirkendrup	498	3031	3883	4973
26	Ringe Skov	456	647	824	1048
27	Søgård	173	838	1059	1338
28	Assens	1247	966	1420	2086

Figure 3: Assessment of the number of car-borne visitors to afforestation areas of the county of Funen. Location of the areas are shown on 0.

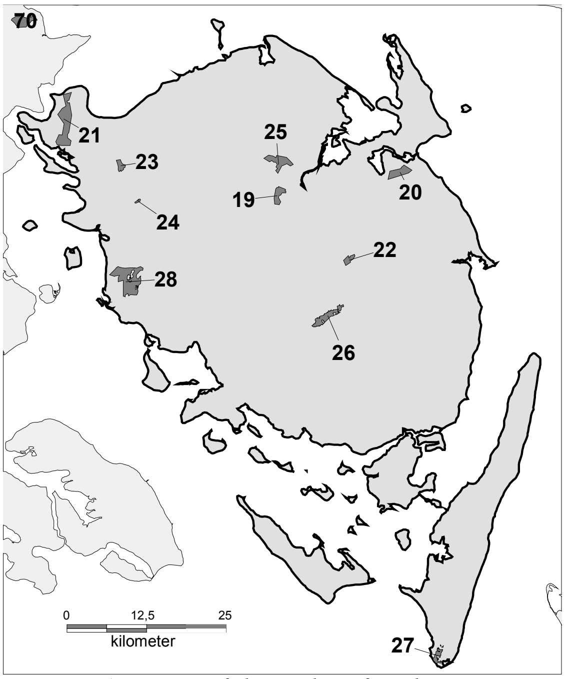

Figure 4: Assessment of the number of car-borne visitors to afforestation areas of the county of Funen. Numbers of the areas corresponds to the index number of 0.

GENERAL ASSESSMENT OF THE POTENTIAL OF AFFORESTATION OF THE DANISH LANDSCAPE

To assess the areas of the country where afforestation potentially would be most beneficial to car-borne recreation the yearly number of visits was estimated for 1000x1000 m. cells for the entire territory (figure 5). With reference to the previous discussion (for further details refer to Skov-Petersen, 2002) and as were the case in the previous section it is assumed that there is no 'intervening opportunity effect' of the introduction of new forest areas. In other words the resulting map cannot be interpreted as what will happen if all Denmark was covered by forest; each cell is evaluated individually assuming that the rest of the relevant land use is unchanged.

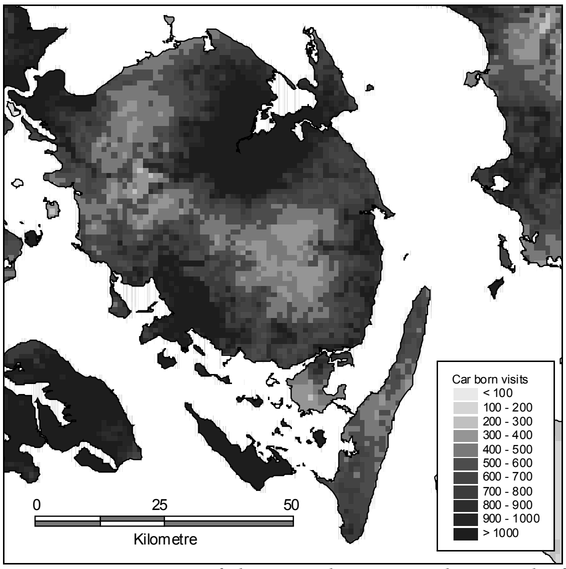

Figure 5: Estimation of the general recreational potential of afforestation of Funen (1000x1000 cells). It is important to notice that afforestation of each individual cell is evaluated independently, i.e. afforestation of adjacent cells does not influence calculation as intervening opportunities.

CONCLUSION

GIS has been proven to be an efficient platform for modeling the recreational activities in Danish forests. 'Reality-data' captured by questionnaire techniques and by registration of the number of cars at parking lots in the nature can be spatially generalized. Hereby it is not only possible to estimate the potential number of visitors to existing forests; it also provides the possibility of predicting the recreational gain by planned forests. The model demonstrated only includes car-borne activities. This is particular a problem in areas close to populated areas because there is a marked tendency of dominance by softer forms of traffic for shorter travel-distances between origin and destination. Further it is problematic that the populations frequency of trips to the nature is assumed to be independent of the amount of local recreational resources. Both the latter issues are obvious fields of future extensions of the work presented.

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