Monitoring and Management of Visitor Flows in Recreational and Protected Areas
Conference Proceedings ed by A. Arnberger, C. Brandenburg, A. Muhar 2002, pages 187-190

# Simulating Visitors' Dispersion in a Nature Reserve based on a Friction Model

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Abstract: A friction model is used for predicting the risk of human penetration of fragile vegetation and bird breeding sites in a nature reserve in central Belgium. The basic components of the study are the terrain classification and the determination of friction values. Different sets of friction values are proposed: based on expert estimation, on walking speed, on energy consumption estimation and on willingness to trespass. The results are compared with spatial data derived from visitor's observations and interviews. The model is to be improved in a later stage by incorporating the effects of visitor's goals, and of attractors and detractors such as vistas, free roaming cattle or physical challenges. The outcome of this study will be used as basis for the evaluation, and eventually of the redesign, of the current management decisions provided in and around the reserve. Also it should help in following-up the effects of the rapidly changing vegetation and terrain conditions on the behaviour of visitors.

## INTRODUCTION

The policy concerning nature conservation is rapidly changing in Flanders (northern region of Belgium). New reserves are being established, often in former extensive agricultural areas. More and more it is being realised that nature protection has to be backed by co-existing functions such as extensive recreation: nature conservation needs continuous and increased official and public support.

The "Demerbroeken" (marshes of the river Demer) is a typical example of a wetland area, formerly used for hay cultivation and later for poplar growing, now being reverted into a mosaic of restored wet hayfields, willow groves, extensive grazing fields, and ponds. The site is situated about 45 km east of Brussels. It retains a multifunctional character, since it not only is a nature reserve, but also a site popular for walking and a floodplain. Apart from a hill at one of the site corners, the whole site is flat. In this study a part of the site of 100 ha is being studied in detail.

The managers have great concern for maintaining an equilibrium between opening up the site for the general public and the protection of fragile parts such as quaking fen (floating organic mats) and bird breeding sites. The whole site is surrounded by habitation area and the general accessibility in the terrain is rather high.

Since it is not the intention to implement hard measures such as fencing off the reserve, which would detract from the overall site value, the central question is how to confine visits to the robust parts of the landscape through the layout of tracks and specific inconspicuous management practices such as selective mowing and discrete boarding.

The intensity of visits is too low and the site too complex and too large to develop on short time a map on visitor's distribution based on systematic observations or enquiries. Therefore an alternative approach is proposed, which uses a GIS based friction model that enables to calculate potential visit intensities at any part of the site, from specified site entrances. The method should terminate in a design and management tool, allowing among other to assess the impact of changes in the infrastructure, season effects or management practices on the distribution pattern of visitors.

This study was started up only a few months ago, and no final results, let alone validations and practical applications can be shown. Therefore, this paper will concentrate on the methodological aspects in the first place.

## METHODS AND TECHNIQUES

There are essentially four methodological parts: the definition of a baseline terrain classification, the estimation of parameters concerning people's preferences and activities in the terrain, the selection of a movement model and the interpretation and validation of the results.

### *Baseline site information*

Aerial orthophotographs from the systematic aerial recording over Flanders in the period 1997-2000 were used for demarcating the habitats of the study area. The term habitat is used here as a vegetation unit with homogeneous structural characteristics such as dominant species (e.g. reed) or species groups (e.g. grass and sedges) canopy height, density, soil conditions, microtopography


*Figure 3. Study area: Demerbroeken (Zichem, Belgium). Habitats are depicted in a greyscale with increasing trespass resistance from pale grey to black. Circles symbolise entrances. This site fragment is about 1 km in W-E transect.*

etc. These are the characteristics that are supposed to be the conspicuous determinants of people's behaviour and movement choices in the terrain. The air photo interpretation is followed by and corrected through field survey. In the field survey a careful mapping, supported by GPS, of all tracks and paths was made, as well as of ditches, fences, dams, information boards, benches and other elements that have an impact on movements in the site. The tracks are also classified in terms of width, vegetation cover, roughness of the surface, wetness conditions and lateral vegetation. All these elements are put into GIS format using ArcView and consequently gridded to 1m resolution. Care is given to preservation of object connectivity in the grid format, especially for linear objects such as tracks and fences.

*Visitors observations and enquiries*

This study aims at making an estimation of the trespassing probabilities in any part of the site. Unlike in city parks of urban forests, the density of visitors in the Demer marshes is rather low and irregularly distributed over the year. Therefore it is impossible to establish a visitors density map based on field observation alone. A more indirect approach is based on an enquiry of groups of people invited to visit the site. At the moment of the submission of this paper, 25 people have been requested to indicate on continuous scales a) their preference judgement concerning preselected sites, b) their preference concerning moving in certain directions, c) their estimation of effort needed to move along certain directions throughout certain types of terrain. In addition to visitors enquiries, the terrain managers themselves were asked to express the different terrain types in terms of walking resistance. These values have been used provisionally as reference.

*Friction model*

The whole site is being interpreted as a continuous area with varied penetrability. The perimeter of the site is considered as an impenetrable edge but for discrete entrances. An isotropic negative growth model is applied, based on the following formula:

$$N_{i+1} = N_i - U*R_{i/i+1}$$

whereby Ni is a residual amount of "energy" in pixel i, U is a fixed unit "energy" that is lost in each transition from pixel i to pixel i+1 and $R_{i/i+1}$ is a resistance or friction factor that is taken into account in the transition from position i to i+1. The "energy" is given as a "start package" to selected objects, in this case the entrances of the site. This energy principle can be alternatively interpreted: effective energy, number of people, walking apparel quality, etc. The formula is being applied isotropically throughout the landscape until exhaust level. Each pixel of the landscape is being reached through a virtually unlimited set of pathways reaching the pixel from different possible orientations. The energy unit along the horizontal or vertical direction in the grid is fixed at 338 for calculation and memory economy in using integer values. The corresponding energy unit for the longer diagonal moves in the grid is 478. Using these two integers, a rounding error of only 0,004 is allowed in the calculations. The lowest resistance value is 1. The initial energy package set at the entrances of the site can be adjusted so as to correspond to the maximal reachable distance in case of overall resistances of 1. The set of friction values assigned to the different terrain classes should correspond to the effective resistances experienced, compared to the lowest resistance terrain conditions of 1, e.g. a flat asphalt road. The resistance values can be defined in different ways: physical walking energy consumption, traversing time, or willingness to traverse different terrain types. The programme used (CONNEC) is basically similar to cost-friction models in several commercial GIS packages, but has some additional possibilities, such as calculating cumulative accessibility, or calculating "walk-sheds" (areas of unique walking origin). The friction model was applied earlier in a project concerning biological connectivity in fragmented cultural landscapes for several species (Villalba et al., 1998; De Genst et al., 2001).

## RESULTS

*The establishment of resistance value series*

Resistance values, defined according to the key expert, are put in a scale 1-100. 100 corresponds to the resistance of a thick reed vegetation. Fig. 2 compares the resistance values according to the key manager in the area and those obtained by measuring the passthrough time. The expert estimation and the timing were set to equal value. The other timing figures were rescaled accordingly.

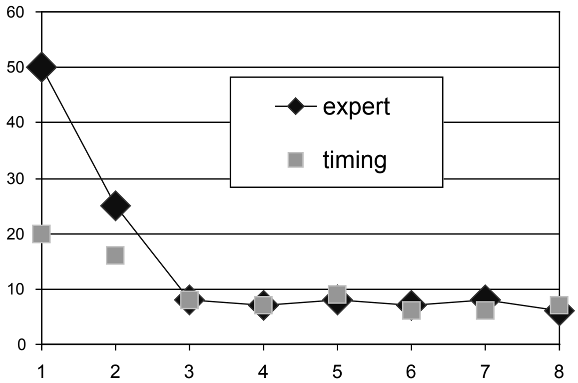
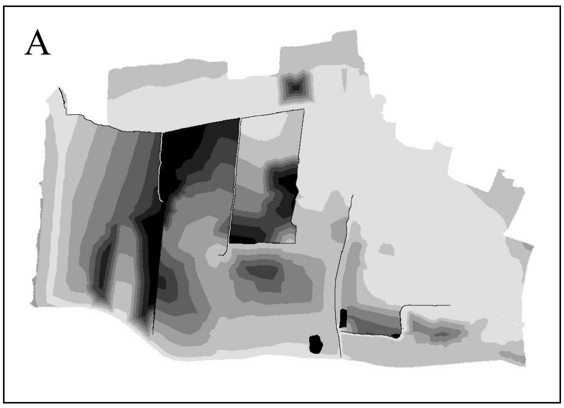


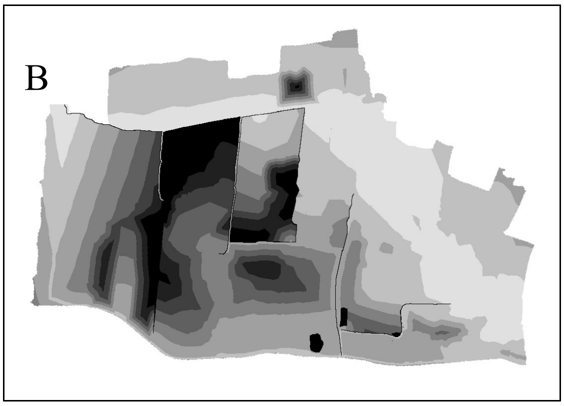

*Fig. 2 Resistance scale 0-100. Comparison between expert estimation and measured passthrough speed (timing) for 8 land cover classes: 1= thick reed vegetation, 2 = woodland with thick understorey, 3= coniferous wood, 4=grazed terrain, 5=mowed quaking fen, 6=medium sized grass, 7= irregular track, 8=track though woodland*

This comparative analysis and reciprocal recalibration is actually being completed by further field investigation. The provisional graph of fig. 1 suggests a similar trend whereby the expert model can be used as reference. The intuitive expert judgement likely is determined by perception of physical resistance and willingness to trespass rather than just attainable speed. Equal speed in sites of different roughness may hide different energy use levels. Therefore a third source of information is the use of effective human energy measurement in different terrain types, such as provided by Montoye et al. (1996). A fourth source is being investigated by enquiring psychological preferences/resistances for entering different terrain types.

*Simulations of terrain access*

Fig. 3 gives three simulations of access. The accessibility is the summation of the residual friction value from the dispersion starting at two entrances. (See fig. 1)



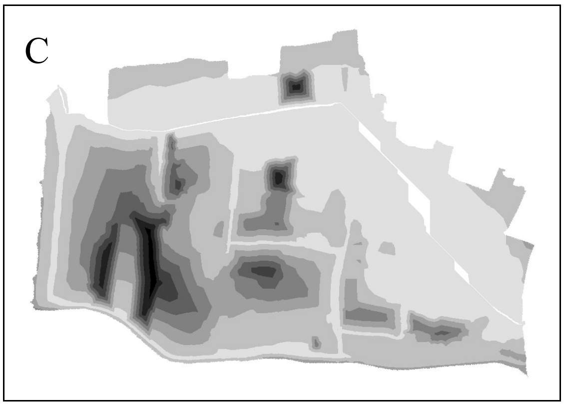




*Fig. 3 Access models. A. With normal friction values for area units and standard friction value (6) for paths. B. Same as A but with differentiated path friction values. C. Same as A, but with friction values of ditches reduced to value 20. Grey shades vary from>80% residual growth value (pale grey) to 0% residual value (black).*

The figures make clear that the friction model reacts sensibly to alternative scenarios. The differentiation of the pathway resistances according to width, surface roughness, wetness etc. changes considerably the overall accessability picture. Also the role of barriers such as ditches or metallic fences can be estimated very sensitively.

Provisional results of enquiries amongst invited people to the site suggest that this will result in well differentiated friction values for different road and surface types. Also, the impact of surrounding landscape characteristics, mystery effects etc. is likely very pronounced on the exact movement patterns. At the other hand, the statistical dispersion of values because of differences in personal characteristics should be taken strongly into consideration.

## DISCUSSION AND OUTLOOKS

The accessability or penetrability model used in this paper has strong potentials for predicting risks of trampling according to the topological situation of fragile habitats. The model is non directional and will consider the whole site as a potential trespass area. Furthermore the model is based on an 'exhaust' principle that to a certain degree mimics human fatigue and preference for the easiest pathways. The model can be used easily for mapping the impacts of changes in the landscape. The model is very sensitive for apparently small changes such as a single footbridge over a stream or the effect of grass mowing, hence opening up more area for trespass. Likewise, the impacts of fencing off, broadening ditches etc. in order to control terrain visit can be easily simulated.

The exhaust principle however ignores possible 'refueling' e.g. by taking into consideration rest periods. The isotropy of the method furthermore does not consider directional factors such as terrain slope, visual attractivity and other goal elements in the landscape. It should be further clarified what exactly such models are capable of simulating: the displacement behaviour of individuals, the average roaming behaviour of groups, the probability of a certain site to be visited etc. Likely this modeling endeavour could be completed by linking several types of models: dispersion models, path finding models (Jöhnsson s.d.), landscape preference models and other.

The resistance or friction values as used in the model can be defined and measured according to different methods. Further comparison of the outcomes of these methods is necessary in order to obtain a useful ranked set of terrain types. An important question is the relation between physical resistances and psychological resistances. It is expected that this research will be able to contribute to this question in a later stage. The seasonal and atmospheric effects are also important factors of variation for the resistance values.

The next research steps will be the comparison of the dispersion calculations with further visitor's behaviour in the site. The low density of visitors however impedes a direct validation. Special emphasis will be given therefore to more indirect validation through enquiries and interviews with groups invited to the site and with local witnesses such as site managers, hunters and frequent visitors.

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