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Identifying tranquil environments and quantifying impacts

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ABSTRACT

The UK has recently recognized the importance of tranquil spaces in the National Planning Policy Framework. This policy framework places considerable emphasis on sustainable development with the aim of making planning more streamlined, localized and less restrictive. Specifically it states that planning policies and decisions should aim to "identify and protect areas of tranquillity which have remained relatively undisturbed by noise and are prized for their recreational and amenity value for this reason". This is considered by some (e.g. National Park Authorities) to go beyond merely identifying quiet areas based on relatively low levels of mainly transportation noise, as the concept of tranquillity implies additionally a consideration of visual intrusion of man-made structures and buildings into an otherwise perceived natural landscape. In the first instance this paper reports on applying a method for predicting the perceived tranquillity of a place and using this approach to classify the level of tranquillity in existing areas. It then seeks to determine the impact of a new build, by taking the example of the construction of wind turbines in the countryside. For this purpose; noise level measurements, photographs and jury assessments of tranquillity at a medium sized land based wind turbine were made. It was then possible to calculate the decrement of noise levels and visual prominence with distance in order to determine the improvement of tranquillity rating with increasing range. The point at which tranquillity was restored in the environment allowed the calculation of the position of the footprint boundary.

1. Introduction

Significant contributions in understanding the essential physical and psychological qualities of tranquil environments have been made [1,2] and these can be applied globally when characterizing restorative space. For the purposes of this study, the extent to which a place is considered to be tranquil is defined by how much individuals think a particular setting is a quiet, peaceful and attractive place to be, i.e., a place to get away from "everyday life".

In common with many advanced economies in Europe and in the Far East the United Kingdom has lost vast tracts of green space both within the inner city and along the urban–rural fringe due to development activity. Despite still having around 27,000 public parks and gardens [3] the number of tranquil spaces in the UK is becoming seriously compromised and has prompted systematic research into tranquillity mapping [4,5]. This work has been conducted along with attempts to define and characterize "quiet areas" in response to the European Directive on the Assessment and Management of Environmental Noise END [6]. Although defining quiet areas in accordance with the END using purely acoustical measures is an important step in protecting tranquil spaces, there is a need to go further and integrate both aural and visual factors into an overall descriptor that will be sufficiently precise and practical.

Previous studies at the Bradford Centre for Sustainable Environments have largely focused on prediction and validation of tranquility ratings in city and country parks using the Tranquillity Rating Prediction Tool (TRAPT) which effectively combines acoustic and visual factors. Highly rated tranquil areas are likely to be restorative providing health and well being benefits as there was shown to be a close relationship between perceived tranquillity of a place and the degree of relaxation experienced [7]. This latest phase investigates how TRAPT can be used for planning purposes by considering firstly how it can be used to monitor the level of tranquillity in a changing situation and secondly how the tool can be used to assess the impact of a specific energy infrastructure project. Based on laboratory studies with participants covering a wide age range, statistically significant factors influencing perceived tranquillity of a place are the noise level and the percentage of natural and contextual features in the visual scene. The TRAPT formula relating these factors [7] is given by:

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$$TR = 9.68 + 0.041NCF - 0.146L_{day} + MF \quad (1)$$

where TR is the predicted tranquillity rating on a 0 to 10 scale (0 is "least tranquil" and "10" is "most tranquil"), NCF is the percentage of natural and contextual features in the landscape and L_{day} is the equivalent constant A-weighted level of man-made noise during daytime (7:00 am to 7:00 pm). Contextual features include listed buildings, religious and historic buildings, landmarks, monuments and elements of the landscape, such as traditional farm buildings, that directly contribute to the visual context of the natural environment. It can be argued that when present, these visually cultural and contextual elements are as fundamental to the construction of 'tranquil space' as are strictly natural features (e.g. grass, shrubs, trees, water, rock etc). MF is a moderating factor that was added to the equation following an earlier study [8], and is designed to take account of the presence of litter and graffiti that would depress the rating, or natural water sounds that would improve it. This minor adjustment is designed to take account of the actual environmental conditions at the time of assessment and is unlikely to influence the calculated TR by more than ±1 scale point.

TRAPT was used in a previous study to assess tranquillity in 8 green open spaces and the predictions were validated using a questionnaire survey of park visitors [7]. A further study was completed using a jury approach to rate tranquillity at 9 locations in a country park. Again it was possible to validate the predictions with average ratings from the jurors [9]. This paper describes and reports on a method of (a) determining and presenting existing levels of tranquillity for planning and monitoring purposes using tranquillity contours and (b) the effects on perceived tranquillity with distance from wind turbines. Of course the methodology could equally apply to a new road, building development, car park or pylons etc, and the example should prove useful in demonstrating how it could be used to meet the new requirements imposed by the National Policy Planning Framework (NPPF) [10]. This Framework requires that planning policies and decisions should aim to "identify and protect areas of tranquillity which have remained relatively undisturbed by noise and are prized for their recreational and amenity value for this reason".

2. Tranquillity surveys

A useful initial approach is to identify the most likely tranquil and non-tranquil places in a defined area and calculate the corresponding range of Tranquillity Ratings, TR, [11] defined in Eq. (1) using:

- Noise maps (if available).
- Spot readings of A-weighted sound pressure levels throughout the area.
- Noise predictions based on official noise prediction software.
- Photographic survey of the percentage of natural and contextual features.

2.1. Classification of tranquillity ratings

This survey method provides the expected range of tranquillity ratings in an area. To provide greater detail it is necessary to calculate the tranquillity rating throughout the chosen area using a grid sampling approach and to map the resulting levels of tranquillity using suitable contouring software.

To provide informative tranquillity maps it is necessary to provide an indication of the quality of the tranquillity rating e.g. acceptable and non-acceptable levels. It has been suggested that the following descriptors of tranquillity level should apply for urban parks and green spaces [11]:

<5 unacceptable
5.0–5.9 just acceptable
6.0–6.9 fairly good
7.0–7.9 good
$\geqslant 8.0$ excellent

Note that for countryside areas these limit values could be increased because expectations for tranquillity are likely to be higher.

To protect tranquil areas it would be useful to provide plots of tranquillity contours which can be monitored in order to indicate changes that might pose a threat. Fig. 1 illustrates cases where the noise from traffic varies and indicates the corresponding changes in the areas of tranquil spaces of various qualities.

Of particular concern would be significant shrinkage of high quality tranquil areas that might be of particular benefit for local residents. The health and well-being benefits of such spaces has been reviewed previously [9,11].

3. Impact assessment

3.1. Predicting tranquillity

The first stage involved collecting data in an around a wind farm located in Ovenden Moor in the district of Calderdale in West Yorkshire. The wind farm consisted of 23 turbines in 2 rows aligned approximately north–south with a ground to rotor tip height of approximately 50 m. Each turbine has a rated output of 0.4 MW. The turbines were built on essentially flat ground at a height of 400 m above sea-level with prevailing winds from the west. While aerodynamic noise produced by the moving blades was dominant it was possible to perceive some gearbox/generator noise at distances less than approximately 100 m. Fig. 2 shows the third octave band levels recorded at 95 m and height of 1.2 m over 30 s with a wind speed <5 m/s showing a broad peak centered at 630 Hz band and a significant low frequency component at 160 Hz.

3.2. Measurements and assessments

Tranquillity assessments were made at a distance of 95 m from a turbine at the end of the most westerly row of turbines as part of a jury experiment previously reported [9]. Thirty participants took part and an average tranquillity rating on a 0–10 scale was obtained. A-weighted noise level measurements were made at a distance of 25 m and height of 1.2 m from the same turbine under different conditions from wind speeds <0.5 m/s, 3–5 m/s and >6 m to determine a typical reference level from which noise level predictions could be made at varying distances. The level ranged from 43 dB (A) at the lowest wind speed to 57 dB (A) at the highest. A value of 55 dB (A) was selected for reference purposes though calculations were carried out additionally at 50 and 60 dB (A) for illustrative purposes. The measurement distance was considered sufficiently close to avoid significant contamination of measured noise levels by other turbines.

3.3. Predictions

To illustrate the calculation method predictions of tranquillity ratings were made for a single turbine and also for a row of turbines (wind farm). The variation with tranquillity is calculated at distances d to the turbine. The ground is assumed flat and grass covered and the turbine blades move in a vertical plane. From the analytical work [12] it can be assumed that the effective center for the noise generation is at or close to the turbine hub at a height of 32 m. The receiver is assumed to be at a height of 1.5 m. The