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Tranquil spaces in a metropolitan area

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ABSTRACT

The literature points to the importance of quiet areas, green spaces and natural surroundings in relieving stress and improving feelings of well being. Such tranquil landscapes and soundscapes are potentially well suited to the needs of citizens of metropolitan areas because the stress of everyday city life can often involve intense periods of 'directed attention' over many hours, leading to stress and mental fatigue. At the University of Bradford in the UK research has provided a unique engineering tool for predicting the perceived tranquillity of open spaces in towns, cities and countryside. The tool has initially been used to carry out a pilot tranquillity audit of 3 open spaces [1] and has now been extended to all 4 major parks in a metropolitan area. The dominant noise source in each case results from traffic on roads close to the boundaries. The results provide useful insights into the levels of tranquillity that can be achieved in such urban conditions and the effects of moderating factors are discussed based on recent research results. Suggestions are made for improving the levels of tranquillity. The paper describes the results of the survey and discusses the trends found if the area of the parks and open spaces is considered.

BACKGROUND

There is an abundance of literature that points to the benefits of natural places both to relieve stress and aid recovery from illness. Tranquillity implies a quiet as well as a natural setting so it goes beyond the concept of "quiet areas" which has been the subject of recent developments in European legislation e.g. the European Directive on the Assessment and Management of Environmental Noise (END). There are a number of studies which indicate that such tranquil places may be beneficial to human health and well being and it is considered that providing, protecting or improving tranquil spaces should be seen as key goals in uban planning. Kaplan has discussed the notion of Attention Restorative Theory (ART) in relation to modern living where many tasks required directed attention such that fatigue and loss of concentration sets in. In natural areas away from the hustle and bustle of everyday life it is possible to let attention wander and often natural events provide "soft fascination" e.g. ducks swimming in a pond, which provides some relief as attentional demand is low in contrast to the demands of many tasks in this increasing technological age. ART proposes that exposure to natural restorative environments can help us recover from the 'sensory overload' that characterises everyday urban life, by providing us with the opportunity to reflect on life's priorities, possibilities and goals [2,3]. A more recent development is an examination of the evidence for "nature-deficit disorder" which is claimed seriously limits the development of children [4]. Exposure to natural environments can also assist in the reduction of stress, improve well being and aid recovery from major illness [5,6].

Ulrich considered how stress might be relieved by natural places [6]. He compared 23 matched pairs of patients who underwent a cholecystectomy (a common type of gall bladder surgery) and the post-surgery patients were randomly-assigned to either rooms facing a brick building, or a room with a view of a natural environment (trees, grassy field). Investigators found that those facing nature had shorter post-operation stays, fewer negative comments from nurses and took less analgesics. It was concluded that viewing nature alone can aid recovery.

In a further more controlled study he exposed volunteers to stressful video for 9 minutes while monitoring a variety of physiological measures [5]. The volunteers were then divided into matched groups with each group subsequently being exposed to a different video. Videos of traffic and shoppers in a mall produced little or no recovery after a further 9 minutes. However, for the group watching the nature video the responses were positive indicating a significant reduction in stress levels.

A further issue that has recently been addressed is the extent to which visual aspects influence auditory perception and in particular the assessment of tranquillity. To understand at a more fundamental level the mechanism leading to these positive changes and the interaction of visual and auditory stimuli, experiments were conducted on the neural responses in the brain. A recent study of 12 male volunteers used functional magnetic resonance imaging (fMRI) to examine the brain's response to tranquil and non-tranquil scenes with the same acoustical input [7]. The scenes were either of a motorway (non-tranquil) or a beach with braking waves in view (tranquil). The significant differences in perceived tranquility were confirmed in a separate experiment using ratings of tranquility on a 0-10 interval scale. The sound was shaped broad band noise which was the averaged spectrum of motorway traffic at some distance from the road and sounds recorded at a surfing beach. Both sounds were perceived as a fairly constant "roar". It was confirmed in a separate experiment that this averaged sound was considered congruent with both scenes. Examining the differences in the brains response

between the tranquil and non-tranquil scenes showed significant differences in connectivity between the auditory cortex and medial pre-frontal cortex. This was interpreted as greater engagement with the tranquil scenes compared with the non-tranquil scenes. Such engagement may lead to the stress reduction observed in Ulrich's studies. Further work is required to determine the level of tranquillity which will provide adequate relief from stress induced by living and working in city environments. Such an outcome would assist in the design of "restorative environments". Not only for the average citizen but for hospital patients and those in various care institutions.

FACTORS AFFECTING TRANQUILLITY

Quiet and natural environments are key features of tranquil spaces. Previous research at the University of Bradford has shown that it is possible to predict with reasonable accuracy the perceived tranquillity on a rating scale using two factors: the average noise level from man-made noise sources and the percentage of natural features in the landscape such as vegetation, water and geological features e.g. exposed rock outcrops [8]. It became clear that other factors need to be considered. Such "moderating factors" as the presence of water and associated sounds and litter and graffiti have been shown to affect ratings of tranquility.

Main factors

Research has been carried out in the laboratory using the playback of video cuts using binaural recordings taken with an artificial head in a variety of landscapes from open moors through beach scenes and residential areas to city centres. The updated formula relating these factors has recently been reported [9]. In the current paper it is convenient to add an extra factor *MF*:

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

Where *TR* is the tranquillity rating on a 0 to 10 rating scales. *NCF* is the percentage of natural and contextual features. 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. L_{Aeq} is the equivalent constant A-weighted sound pressure level, which for practical application should be the level of man-made noise over the day time period. *MF* is an adjustment due to moderating factors which are the subject of ongoing research. Some moderating factors which in most cases are not expected to be large are described below.

In order to develop the tranquillity rating method, assessments were obtained from subjects under controlled simulated environments in an anechoic chamber. The subjects were provided with headphones and positioned 2m from the centre of a large plasma screen. They were then asked to rate how tranquil they found 34 locations to be when presented with audio only, video only and combined audio-video data streams. Each location was scored on a scale of 0 – 10, with 0 representing 'not at all tranquil' and 10 representing 'most tranquil', and the stimuli were presented in a balanced design intended to reduce order effects. Prior to the experiment the subjects were told that for the purpose of the research a tranquil environment was one that they considered a quiet, peaceful place to be, i.e. a place to get away from everyday life. This laboratory method has recently been validated by comparing assessments made outdoors with those made in the laboratory [10]. The correlation between these two sets of rating was high ($R^2 = 0.95$) giving confidence in the results of these studies for outdoor assessments of tranquillity. In addition to the main factors other moderating factors should be considered.

Moderating factors

In further studies the effects of water sounds of various types and presence of litter were examined experimentally.

Water sounds

One potentially effective solution to improving tranquillity is to mask traffic noise or distract attention with an attractive water sound. It has been shown in a recent survey [11] that visitors to a range of countryside locations have a preference for soundscapes with prominent natural sounds such as from streams or waterfalls even though sound levels can be relatively high. A previous experiment has demonstrated that water generated sounds have the potential to improve the perceived tranquillity of gardens blighted by noise [12]. In this study a hydraulics rig was set up at the University of Bradford where the flow of water, drop height and plunge pool could be controlled. In the pool was placed a variety of stones, bricks and gravels. Recordings of a variety of sounds produced from a low waterfall were taken. These digital recordings of the sounds of falling water on different types of surface were replayed to 14 subjects together with background traffic noise at different levels. Assessments were made under controlled conditions in a simulated garden constructed in a semi-anechoic chamber. Subjects were asked to rate the change in tranquillity due to the addition of the water sounds. It was shown that there was a highly significant difference ($p<0.001$) between water sounds in changing the perceived tranquillity.

Further assessments were made concerning the nature of the sounds and it was concluded that the more natural the sound the greater the average tranquility score. For example sounds that were considered to be similar to rain or a babbling stream were more highly rated than sounds that resembled water falling into a drain. It is necessary to carry out further research in order to quantify the benefits of water sounds in a way that can be used to adjust the ratings given by equation (1).

Effects of litter

As part of a validation study designed to test whether ratings made indoors in simulated environments gave similar results to those given outside in the real environment, use was made of an experimental garden ("Peace Garden") at the University of Bradford [10]. This small garden with flower borders and a water feature is located on the edge of a major road to the city centre but screened to some degree by a 1.8m high serpentine wall. Two of the conditions presented to the 8 subjects who took part included views of the garden with and without litter present. On the 0 to 10 scale of tranquility it was shown that the average rating decreased from 4.6 to 3.6 when litter was present i.e. a 1 scale point reduction in the tranquility rating.

Although this finding is from a small study, in the absence of more data such an adjustment to the rating should be considered after the main factors in equation (1) described above have been taken into account.

Other factors

The experiment described in reference [10] also collected data on factors that affected the perceived tranquility. Subjects were asked to note on a questionnaire any features in the scenes they were shown that either increased or decreased tranquility. The factors increasing tranquility in order of fre-

quency of mention were: sound of water, trees, shrubs, flowers, grass, quiet, peace, low noise, open space, views, old buildings, wind in trees, sunshine, bird song. The factors decreasing tranquilliy in order of mention were: traffic noise, noisy people (including music), litter, sound of water (recorded), ugly buildings, paths, signs, vehicle noise (reversing alarms, ice-cream chimes, building site view, dirty conditions (exclude litter), excessive wind noise in trees, sound of water (natural), construction noise. Without further controlled experiments it is not possible to quantify the effects of all these factors.

SURVEYS OF GREEN SPACES

In order to use the prediction tool (equation (1)) in practice it is necessary to consider appropriate sampling techniques which will identify the range of likely tranquillity ratings in the chosen areas and then to consider adjustments or moderating factors. A further step is to address inadequacies by "what if" analysis. In order to assess the levels of tranquillity in a densely populated area, surveys were carried in the 4 major parks in the Bradford City area using the tranquility rating prediction tool described above. This extends the work carried out in an initial study of open spaces [1]. The dominant source of noise in all these parks and open spaces was road traffic. Only the flows on the busiest roads directly adjacent to the park boundaries are given below.

• Lister Park: Triangular in shape adjacent to a major radial route into the city centre with a day time flow of 1300 vehicles/hr. Contains mature, trees, formal gardens, iconic building (Cartwright Hall) and boating lake, water features, sports area and children's playground.

• Peel Park: Irregular in shape with duck pond, formal gardens, mature trees, large statues, childrens' play area and sports fields. A roads runs along the north boundary for part of the way with a day time flow of 336 vehicles/hr.

• Bowling Park: an irregular shaped space with a road running along the length of the northern boundary with a daytime flow of 384 vehicles/hr. Contains mature trees and shrubs, few formal borders and playing fields to the south

• Horton Park: Rectangular park with fairly busy road on north-west boundary with daytime flow of 582 vehicles/hr. Contains mature trees and shrubs, formal gardens, pond with bridge and stream

• Peace Gaden: a small rectangular space (approx. 55m x 14m) on the edge of the University of Bradford campus and adjacent to a route into the city centre with a day time flow of 1060 vehicles/hr. Recently developed to include 1.8m high noise screening wall, herbaceous borders containing mature trees and a small pond with water feature.

• Thackley Green: a simple rectangular grassed open space (approx. 100m x 35m) with few trees and no formal gardens. Adjacent to a major route to Leeds and with an industrial estate to the rear. Day time flow 910 vehicles/hr.

The approach was to identify the most likely tranquil and non-tranquil spaces in these open spaces and calculate the Tranquillity Rating using:

• Noise maps provided by DEFRA

• Spot readings of A-weighted sound pressure levels

• Noise predictions based on the UK traffic noise prediction model CRTN

• Photographic survey of the percentage of natural and contextual features

Noise maps

The noise maps of this metropolitan area or agglomeration are published on the DEFRA website at:

www.http://noisemapping.defra.gov.uk .

They were used to help identify the likely nosiest and quietest areas in the selected parks and greens. The noise bands are given in L_{den} and are in 5 dB(A) intervals down to 55 dB(A). Levels below 55dB(A) are not differentiated. L_{den} by definition includes day, evening and night-time levels, weighted according to sensitivity, and therefore are not directly relevant to the daytime use of the parks in question. To convert to L_{day} (average day time level from 7am to 7pm) a formula derived for the UK national survey was used [13].

$$L_{day} = 0.984\, L_{den} - 0.196 \quad (2)$$

Spot readings

During the photographic surveys, spot readings of the A-weighted sound pressure level were taken of background noise levels which were dominated by traffic noise. Periods of significant natural sounds were excluded (e.g. bird song) as were human voices and the noise from any mechanical tools. In conjunction with the noise maps the quietest and nosiest locations were located. GPS co-ordinates were recorded using a hand held device (Garmin eTrex HC) at these locations.

Noise predictions

Since the dominant noise source at each site was road traffic noise, predictions were carried out at the sites using CRTN [14]. This method predicts the 18 hour L_{A10} value from 0600 to 2400 hours. Classified traffic counts were carried out and distances to the nearest road calculated using GPS co-ordinates previously recorded. At all sites the road surface was essentially level with a bituminous wearing course and subject to a 48 km/h (30 mile/h) speed limit.

It is suggested that this method is used where an accurate prediction is required. The L_{day} can then be obtained from the official conversion formulae [15]:

For non-motorways: $L_{day} = 0.95\, L_{A10,18h} + 1.44$ dB (3)

For motorways: $L_{day} = 0.98\, L_{A10,18h} + 0.09$ dB (4)

Note that where CRTN is not the preferred prediction method other validated traffic noise models can be used to obtain L_{day}. Where noise from other transportation modes dominate the L_{day} value can be calculated using the appropriate prediction model.

Photograpic survey

Having identified the quietest and noisiest areas from the relevant noise maps and spot readings, the percentage of natural and contextual features was determined using a camera giving a field of view of approximately 51 degrees in the horizontal plane on a normal (non-zoom) setting. Seven contiguous pictures were taken at a height of 1.5m (close to the average standing eye height of adults in the UK) to give an approximate field of view of 360 degrees. These pictures were analysed using a 10 x 10 grid placed over the images to determine the percentage of natural and contextual features.

Note that in all cases the quietest areas also had the highest percentage of natural features so according to the prediction tool this would also be the most tranquil. Survey positions were chosen close to park benches which were always positioned on bituminous surfaced paths. It was observed that few people crossed grassy areas or walked through or over plants and vegetation.

ANALYSIS

As an example the results of the photographic survey for Lister Park are summarised in Figure 1. The thick dark blue lines indicates the percentages of natural and contextual features for the positions with the highest levels of tranquillity and the thick light blue line shows the percentages at the positions with the lowest tranquillity. In all cases positions in the park away from the busiest roads were predicted to be most tranquil. Being away from the major road, lawns, trees and contextual buildings and walls tended to dominate the scenes. Close to the park boundaries with higher noise levels from traffic the scenes included vehicles, housing or industrial buildings.

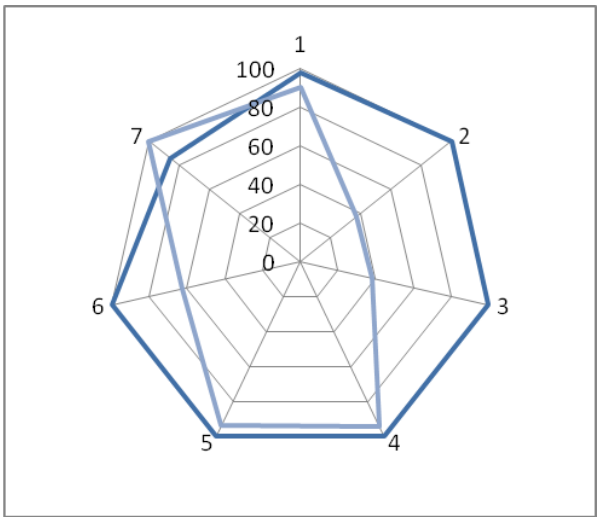

Figure 1: Percentage of natural and contextual features in each direction at least and most tranquil parts of Lister Park

Table 1 summarises the calculated L_{day} values using the noise prediction method CRTN and the percentage of natural and contextual features from the photographic survey together with the corresponding predicted Tranquillity Rating.

DISCUSSION OF PREDICTED RATINGS AND ADJUSTMENTS

It can be seen that the predicted tranquillity rating ranged from 0.0 adjacent to the main road at Thackley Green to 7.3 near the centre of Peel Park where the most tranquil space was to be found. Based on past experience the following guidelines in describing the levels of tranquillity in urban green spaces are given:

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

Table 1: Predicted tranquillity ratings

Location	L_{day} (dB(A))	Percentage of natural and contextual features	Predicted tranquillity	
			Rating	Category
Peel				
Near centre	44.2	99.2	7.3	Good
Near north boundary	58.0	88.3	4.8	Unacceptable
Horton				
Near centre	43.5	85.3	6.8	Fairly good
Near south boundary	55.9	78.8	4.7	Unacceptable
Bowling				
Near centre	47.3	87.8	6.4	Fairly good
Near north- west corner	50.8	82.2	5.6	Just acceptable
Lister				
Near centre	51.8	97.7	6.1	Fairly good
Near south-west boundary	71.1	73.7	2.6	Unacceptable
Thackley Green				
At rear	60.4	56.1	3.2	Unacceptable
Near south boundary	75.7	27.3	0.0	Unacceptable
Peace Garden				
At centre	60.7	55.6	3.1	Unacceptable
At east entrance	70.0	30.9	0.7	Unacceptable

If these descriptors apply then from Table 1 it can be seen that the highest level in Peel Park falls in the "good" category. The traffic noise on the roads to the north and west are effectively screened by walls and 2 storey buildings and to the fact that substantial areas lie in a hollow at a level below these roads. The other parks reach an estimated "fairly good" level of perceived tranquillity. The range of tranquillity experienced in each park varies such that the greatest range was predicted for Lister Park (2.6 to 6.1) and the smallest for Bowling Park (5.6 to 6.4). The higher range at Lister Park is in part due to the highly trafficked radial route into the city centre and the lack of screening adjacent to this road. For example there is a lack of high boundary walls or buildings between this road and the park. In contrast Bowling Park has a much lighter traffic flow at the boundary and there are substantial stone walls with few gaps providing significant screening.

Adjustment to ratings

As noted above, there are a number of factors that are not contained within the prediction tool which are likely to degrade or improve the tranquillity rating beyond that which has been predicted by the variables L_{day} and NCF in equation (1). These include social and personal safety factors. It was shown that the presence of litter decreases the tranquillity rating by one scale point and it is likely that the presence of graffiti would have a similar effect. Lister and, to a lesser extent, Peel parks had little or no litter or graffiti in the most tranquil areas and so adjustment to the highest ratings is considered unnecessary. However, in the case of Horton and Bowling parks, there was evidence of litter, and graffiti on park benches, throughout the parks and on a water feature in Bowling park which was no longer operating. In these cases a reduction of a scale point is considered appropriate which would result in the predicted highest levels of tranquillity being "just acceptable" rather than "fairly good". The small water feature in the Peace garden may have a beneficial effect although the water sound produced is only just audible at 10m due to the high traffic noise levels.

Improvements

To obtain improvements in levels of tranquillity where currently predicted ratings are unacceptable or only just acceptable it will be necessary to consider:
(a) Reducing transportation noise

(b) Increasing the percentage of natural and contextual features
(c) Improve maintenance e.g. removal of litter and graffiti
Due to their relatively large areas (resulting in lower noise levels due to distance attenuation) and fairly light traffic flows on the major boundaries, Peel, Bowling and Horton Parks have reasonable levels of tranquillity throughout significant areas of the park. However the study has highlighted short comings at Lister Park which results from its position next to a major road, that runs alongside its longest side and the lack of effective screening of traffic noise from this road. Thackley Green and the Peace Garden open spaces are both adjacent to heavily trafficked roads and the survey results highlight the problems of achieving high levels of tranquillity due to small size and lack of effective screening. Improved screening of traffic noise could be provided by a wall or substantial fence of appropriate height and length. It should be noted that the wall at the Peace Garden is a fairly modest 1.8m in height. A further possibility is the use of a lower noise road surface wearing course such as porous asphalt or stone mastic asphalt with small stone size (e.g. 6mm). Note that increasing the percentage of natural or contextual features is not thought to be so critical in the 4 largest parks as levels were generally high especially near the middle as was expected. In the 2 smallest open spaces the percentage of natural features even near the middle was relatively low due to the closeness to the road and surrounding buildings. Improvements to the paths in the parks e.g. resurfacing to produce a more uniform and pleasing appearance and improved edging would lead to these areas being assessed as "contextual". The provision of appropriate water features and ponds could be considered for Bowling Park as this is known to improve levels of tranquility as described above. Note that in Lister Park there is an abundance of water features, a lake and stream with cascades and waterfalls, which should improve rated tranquillity over and above that predicted. On average approximately a third of a scale point adjustment was given for replayed water sounds in the recent experiment that was described above [10] but no water feature was in view and the replay quality was poor. It is estimated that an appropriate water feature, "natural" stream, lake or pond would raise the rated tranquillity by at least one scale point. However, further research is required to quantify the degree of improvement with more precision. If the one scale point correction was applied to Lister Park the most tranquil rating would fall into the next higher category i.e. "good" rather than "fairly good" which is considered a more appropriate rating. The ratings in Peel and Horton parks could likewise be adjusted upwards by one scale point because of the presence of ponds near the most tranquil positions. This would return Horton Park to the original prediction of "fairly good" (after a 1 point penalty for litter – see above) but raise Peal Park to the next category i.e. "very good". In the case of Thackley Green and the Peace Garden the tranquillity ratings were relatively low (3.2 and 3.1 respectivey) making it very challenging to effect sufficient changes to provide acceptable tranquillity.

Effect of park area

From the analysis above it is clear that the area of the park has an important influence on the maximum tranquillity that can be achieved due to (a) effects of distance in attenuating traffic noise emanating from the boundary roads and (b) the provision of a high percentage of natural features. To understand the effects of size more clearly the situation was modelled making simplifying assumptions. It was assumed that:

- Parks were square
- The most tranquil space was at the centre of the square
- The road carried heavy traffic along one side only and that the flows on other sides could be ignored
- The traffic flow was that recorded at the busiest site i.e. Lister Park (1300 veh/hr)
- The traffic noise from the busy road was effectively screened by buildings beyond the limits of the park boundaries i.e. the line source was considerd as extending only along the length of one side
- The park was flat grassland with no significant screening at the boundaries
- That CRTN could be used to model the propagation of traffic noise over the sizes considered i.e. length of one side ranging from 25m to 1600m.

Separate calculations were carried out for *NCF* values of 0%, 50% and 100%. Figure 2 shows the linear relationship that was found to exist between the predicted tranquillity rating at the centre of the parks when the logarithm of area was used as the measure of size (note 1 hectare=10,000m^2). The effect of park size is clearly displayed. The trend lines also show the significant effect of the percentage of natural and contextual features. With dense plantings on the boundaries it should be possible to achieve acceptable tranquillity for parks of only 1 hectare.

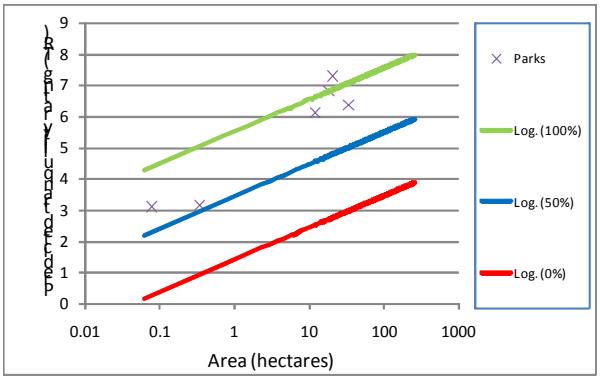

Figure 2: Predicted tranquillity rating variation with area

Plotted on Figure 2 are the 6 parks and open spaces surveyed. It can be seen that all the relatively large parks of over 10 hectares have at least fairly good tranquillity ratings and close to the trend line of 100%. However, the smaller spaces with areas less than 1 hectare have unacceptable tranquillity ratings with the plotted points lying close to the 50% trend line. This is due to the close proximity of roads and buildings to the centres of these relatively small areas.

CONCLUSIONS

The highest categories of tranquillity achieved in the 4 largest parks after adjustments were "very good" for Peel Park, "good" for Lister, "fairly good" for Horton Park and "just acceptable" in Bowling Park. The categories for Horton and Bowling parks could be improved with further maintenance. More expensive measures would involve reducing traffic noise levels, improving park paths and the provision of water features. Overall the results were considered surprisingly good, bearing in mind the fact that these four parks are embedded in densely populated urban areas within 3km of Bradford city centre. However, the 2 smallest open spaces of less than 1 hectare performed poorly with unacceptable tranquillity ratings. Increasing the percentage of natural features up to close to 100% is predicted to increase tranquillity to "just acceptable".

A further consideration is that tranquil spaces are often under threat due to increased traffic and aircraft flyovers and the building of new highways and runways to relieve congestion and reduce journey times. It is widely recognised that valued tranquil spaces should be protected from further erosion. For example the European Directive on the Assessment and Management of Environmental Noise (END) [16] has identified the importance of so-called Quiet Areas. The END requires EU Member States to identify these areas in agglomerations. As part of the Action Plans that follow noise mapping, policies should be developed to identify valued tranquil areas and once identified an effective means of protection should be put in place. Such actions have been suggested for quiet areas [17].

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