The effects of "greening" urban areas on the perceptions of tranquillity

Greg Watts
Bradford Centre for Sustainable Environments, Faculty of Engineering and Informatics, University of Bradford, UK.

Rob Pheasant
Bradford Centre for Sustainable Environments, Faculty of Engineering and Informatics, University of Bradford, UK.

Summary
A number of studies have been conducted at the Bradford Centre for Sustainable Environments at the University of Bradford which have examined the effects of natural features on ratings of tranquillity. These include quantifying the effects of the percentage of natural and contextual features and man-made noise on rated tranquillity. Recently the resulting prediction equation TRAPT (Tranquillity Rating Prediction Tool) has been used to examine a number of scenarios including city parks and squares, country parks and moorland areas and to relate predictions to ratings made by visitors to these green spaces and reported levels of relaxation. The tool has also been used for predicting tranquillity in city squares of different sizes, to examine tranquillity behind natural (green) and manufactured noise barriers and to assess the benefits of "greening" streets in urban areas using avenues of trees, hedges and grass verges. The paper reviews these studies and gives examples of the extent to which introducing vegetation is predicted to provide benefits.

PACS no. 43.50.Rq, 43.50.Sr

1. Introduction

Recent studies [1] have demonstrated that the tranquillity construct is essentially composed of two components i.e. pleasantness and calmness. It has been found that over the population as a whole most people prefer natural sounds to man-made sounds and green environments to built environments [2]. To translate these ideas into a practical prediction tool that can be validated has been the focus of studies at the Bradford Centre for Sustainable Environments. It was shown that for urban areas the form of the prediction equations is [3]:

$$TR = 10.55 + 0.041\ NCF - 0.146\ L_{day} + MF \qquad (1)$$

Where TR is the tranquility rating on a 0 to 10 rating scales. NCF is the percentage of natural and contextual features and L_{day} is the equivalent constant A-weighted level during daytime (e.g. from 7am to 7pm) from man-made noise sources. The behaviour of this equation has been studied by examining trends in TR with L_{day} at different levels of NCF. It was noted that at the extremes of L_{day} where TR becomes greater than 10 or less than 0 then TR values are set to 0 and 10 respectively. MF is a moderating factor that was added to the equation following an earlier study [4], 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.

For the interpretation of TR values it is suggested that based on the author's collective experiences the following guidelines should apply [3]:

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

These values have been related to the level of relaxation of people after visiting such spaces e.g. for a *TR* value of 5.0 ("just acceptable") nearly 50% of visitors report that they are "more relaxed" after visiting the park while at a value of 8 ("excellent") approximately 80% report being "more relaxed". These categories will be used in interpreting the results in this paper.

2. Method

2.1. Noise predictions

Using equation (1) a number of common scenarios were modeled. Noise predictions of $L_{A10,18hr}$ were carried out using the UK traffic noise prediction method "Calculation of Road Traffic Noise" [5] and subsequently converted into L_{day} [6]. Typical traffic flows and compositions were assumed to cover both main road situations and residential roads and shopping streets. For main roads a two way flow of 1200 veh/hr with 10% heavy vehicles was assumed. For residential/shopping streets a lower flow of 300 veh/hr with 10% heavy vehicles was used. These were based on previous surveys of traffic volumes on radial routes and residential roads into the city of Bradford in West Yorkshire, UK. A hard bituminous surface for these roads was also assumed and the speed limit in all cases was 30mile/hr (48km/h). The road width in all cases was assumed to be 8m. The receiver height for prediction purposes was 1.5m which is similar to the average eye height of a standing adult [7].

2.2. Percentage of natural and contextual features

As in previous studies in order to calculate the percentage of natural and contextual features an eye height of 1.5m was also assumed. The field of view was restricted in the vertical plane to ± 20 degrees. This was approximately the angle of view using a standard camera lens and relates well to studies of the eye's central field of view i.e. the angle over which objects can be recalled without moving the eyes [8]. In the horizontal plane calculations were made over 360 degrees as it is assumed that the observer would make scanning movements in the horizontal plane to take in the full scene. These assumptions were made in earlier surveys which found a close relationship between predicted tranquillity using such a measure and average ratings given by participants visiting a variety of open spaces [3].

Calculations were made of the variable *NCF* at 5 degree intervals over 360 degrees in the horizontal plane and the average value taken. The value *NCF* is given by:

$$NCF = \frac{\sum_{\theta=0}^{N} \frac{An_\theta .100}{(At_\theta)}}{N} \qquad (2)$$

Where An_θ and At_θ are the angles in the vertical plane subtended by natural features and total angle excluding sky respectively, at angle θ measured in the horizontal plane.

2.3. Scenarios

A number of scenarios were examined. These included:

1. City squares of various sizes where a main road was adjacent to one side. The effects of minor road traffic on the other three sides was not considered significant. For each size of park predictions were made in the centre of the square with a 90 degree angle of view of the main road due to the presence of tall buildings on each side of the square (see Figure 1). High traffic flow is assumed.

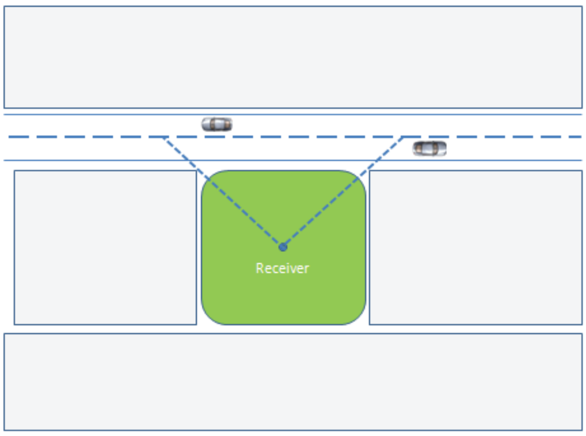

Figure 1: City square showing receiver at the centre with 90 degree view of main road due to tall buildings

2. A park adjacent to a main road where the effect of distance from the kerb was examined and screening of the road and buildings opposite was studied (see Figure 2). It was assumed that the road is very long so the angle subtended by the road is approximately 180 degrees. High flow conditions were assumed.

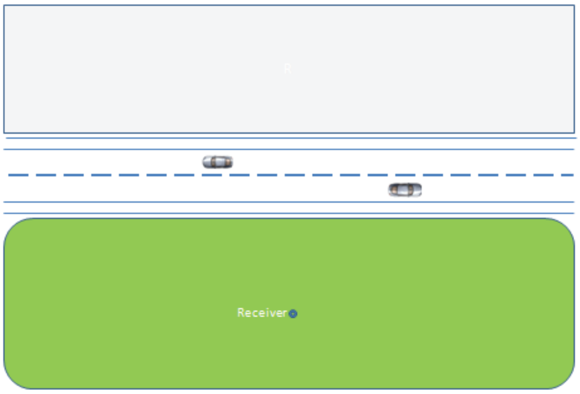

Figure 2: Park adjacent to long straight road with receiver placed at different distances from road

3. Similar to scenario 2 except a 4m high barrier is used to screen the road (see Figure 3) from a garden. The barrier is either "natural" or "manufactured". Examples of the former type are earth banks, barriers constructed from growing willow or dead woven willow covered with growing ivy or simply a manufactured barrier screened from view with vegetation. Examples of a range of such natural barriers are given in reference [9]. Examples of manufactured barriers would be those fabricated from metal, plastic or timber planking. In both cases the barrier is placed at a distance of 4m from the kerb. Again the effects of distance are examined and the presence of a line of buildings 10m high behind the receiver is in addition assessed.

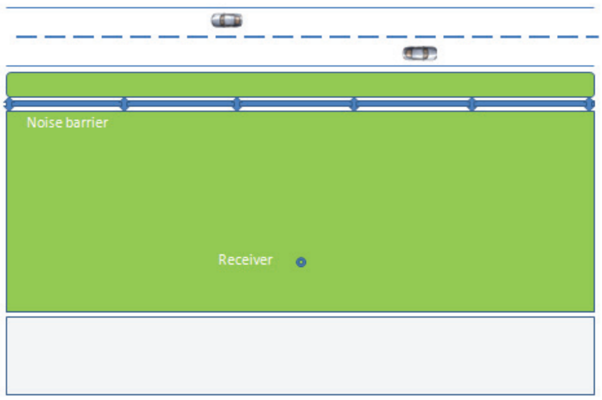

Figure 3: Garden behind noise barrier with effects of 10m high building facades behind the receiver examined

4. In this scenario a grassy verge of various widths was examined on both sides of the road (see Figure 4). Houses 10m high were assumed on both sides of the road. Front gardens were 6m deep and the receiver was placed in the middle of a 2m wide pavement between front gardens and grass verge. Low traffic flows were assumed.

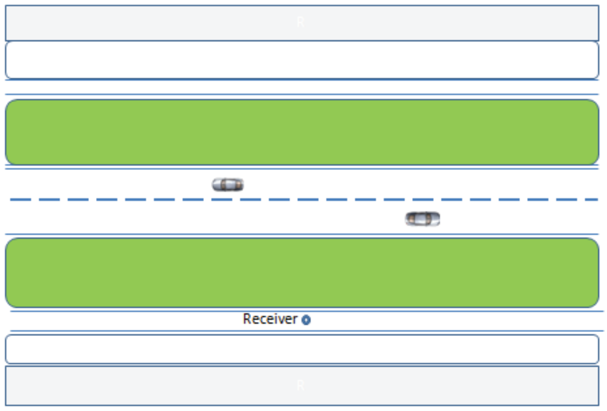

Figure 4: Effects of verges of various widths with facades 10m tall in view on both sides of road

5. In this scenario (see Figure 5) a residential road with low traffic flow has tall hedges in the front gardens (6m deep) adjacent to the pavement (2m wide) so that the 10m high facades on both sides of the road are effectively screened from view. The receiver is 1m from the kerb.

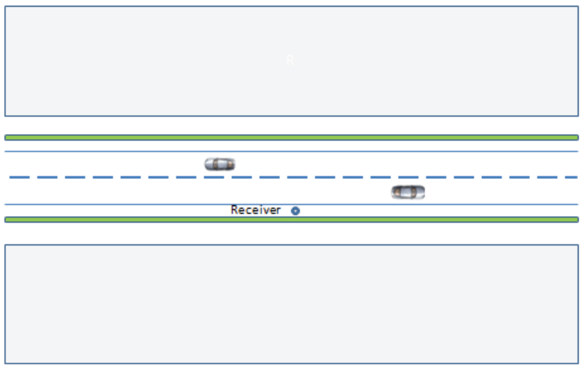

Figure 5: Effects of screening facades 10m tall on both sides of a residential road with tall hedges in front gardens adjacent to the pavement

6. This scenario shown in Figure 6 is a shopping street with 6m wide pavement. Next to the kerbs on both sides of the road are 2m strips where vegetation screen the opposite facades. The receiver is placed 2m from the façade that is unscreened. Low traffic flow is assumed.

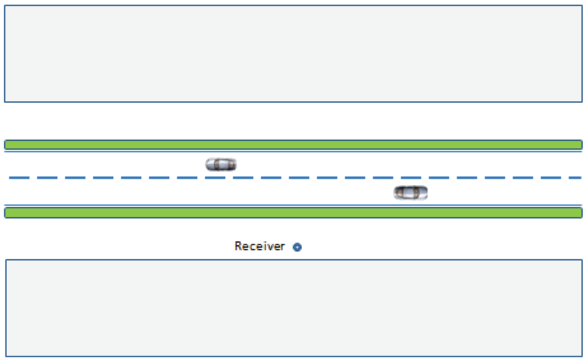

Figure 6: Wide pavement with kerbside screening of opposite facades 10m high on farside of road

Note that in all these scenarios it is assumed that the screening vegetation has an insignificant effect on noise levels. Usually wide belts of dense vegetation (e.g. 30m) are required to achieve significant reductions in traffic noise of several decibels when compared with the typical grassland assumed in these scenarios [10].

3. Results

3.1 Scenario 1

Figure 7 shows the effects of area on the predicted tranquillity rating. Two plots show the effects of different levels of *NCF* i.e. 0% and 100%. In the case of 0% it is assumed that the ground is hard and in the case of *NCF* = 100% the squares are grass covered with trees and hedges screening façades at the park boundary and consequently soft ground corrections are applied in these cases [5].

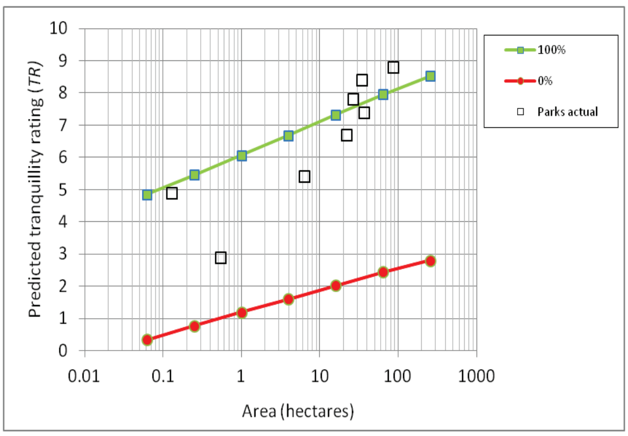

Figure 7: TR at the centre of city squares of different areas

Also plotted are average ratings given by park visitors from surveys carried out in 8 parks of different sizes in the Bradford metropolitan area [3]. It can be seen that with full screening of surrounding buildings a small square of side 32m (0.1 hectares) is predicted to have a tranquility rating of 5. From previous studies this is considered ("just acceptable"). However, with no screening and an acoustically hard surface (e.g. paving stones with no vegetation) the rating would be close to zero. A much larger square of side 1km (100 hectares) would produce an "excellent" *TR* of 8 at its centre if buildings on the perimeter were screened and ground was grass covered. However, with a hard surface and no screening it is predicted that the *TR* would remain low at <3 over the range of distances examined. Note that for the parks sampled in the park surveys [3] there was a tendency for *TR* to be below predictions for smaller parks with *NCF* = 100%. This was due to tendency for smaller parks to have little screening with few trees or hedges whereas the larger parks were not simply grass covered but had an abundance of hedges and trees that effectively screened buildings and roads at the boundary.

3.2 Scenario 2

Figure 8 shows the effects of distance from a long straight road where the ground is grass covered and the road and adjacent buildings are screened. Also shown is the case with a hard surface and unscreened buildings.

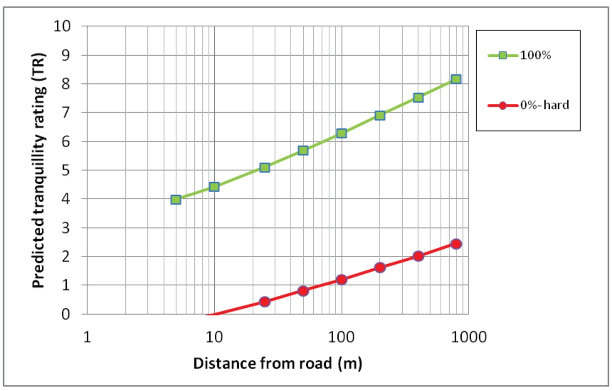

Figure 8: The effects of distance from a main road under two conditions

In the case with grass covered ground and screened road and buildings it is predicted that at a distance from the kerb of 20m a "just acceptable" *TR* value of 5 is achieved. To obtain a *TR* value of

8 ("excellent") it is estimated that a distance of approximately 800m from the road is required. Without screening and with a hard surface it is not possible to achieve a *TR* of 5 even at a distance of 800m. In fact at that distance the predicted *TR* value is only 2.5.

3.3 Scenario 3

Figure 9 shows the effects of introducing a 4m high noise barrier alongside the main road described above. In the first case the barrier is assumed to be a natural barrier (or a manufactured barrier screened from view with vegetation).

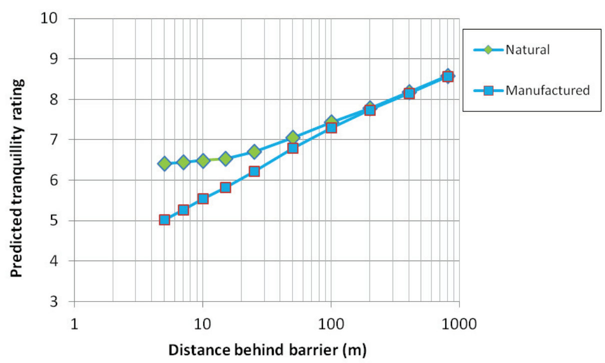

Figure 9: Variation of TR with distance behind a 4m high barrier with natural and manufactured barriers

In the second case the barrier is manufactured and is unscreened. There is a 1.5 scale point difference at 5m but beyond 25 m the difference is less than 0.5 units. In both cases the *TR* values are ≥5 for the distances examined.

Figure 10 examines a related case with a manufactured barrier and unscreened facades behind the receiver.

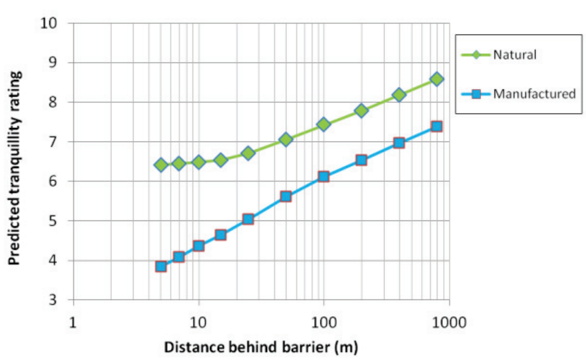

Figure 10: TR as a function of distance behind a 4m high barrier with natural barrier and screened façades behind the receiver and manufactured barrier with unscreened façades

It can be seen that close to the barrier (i.e. 5m) there is now a larger difference of 2.5 units between *TR* values predicted for natural and manufactured barriers. Beyond this distance there are smaller differences but there is always at least a 1 unit difference. The natural barrier provides "fairly good" to "very good" tranquility ratings at all distances examined if buildings behind are screened from view.

3.4 Scenario 4

In this case the effects of a verge of different widths on *TR* in a residential road with low traffic flows were examined. Facades are unscreened both behind and in front of the receiver. Figure 11 shows the trends with soft (grass verge) and hard ground (paved or asphalt).

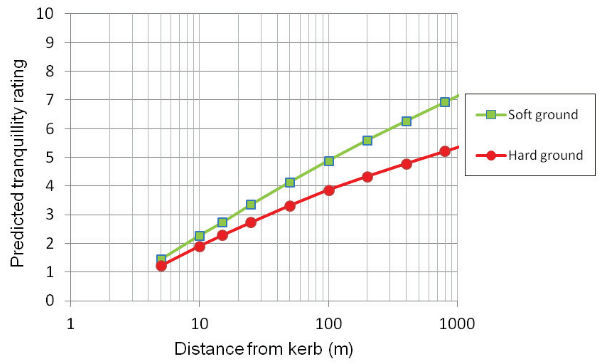

Figure 11: TR as a function of distance from kerb in a residential road with low traffic flow with both soft and hard ground

As expected it can be seen that the benefits increase with the distance from the kerb though this increase is more rapid with soft ground. This is due to the sound absorption of the grass covered ground.

"Just acceptable" levels of *TR* (i.e. 5) are reached at a distance of just over 100m in the case of soft ground (e.g. grass covered) while for hard ground, such as paving or asphalt surface, the distance is approximately 800m.

3.5 Scenario 5 and 6

In these cases the effects of distance were not examined as the scenarios envisage buildings relatively close to the road. In these cases low flow conditions are assumed. In scenario 5 where tall hedges are in front gardens adjacent to the paths that effectively screen from view facades on both sides it was found that despite this "greening" the predicted value of *TR* is relatively low at 3.0. However, without screening the value drops to zero. In scenario 6 with wide pavement the screening vegetation is at the kerbside and so it is only opposite facades that are screened from view. With this screening a *TR* value of 2 is predicted while without this visual screening a low value of 0.4 is predicted.

4. Summary and conclusions

The effects on predicted perceived tranquility of town squares, city parks, residential roads and gardens and shopping streets have been examined. It is clear that visual screening of buildings with vegetation, noise reduction through the use of soft ground (e.g. grassy areas) and sufficient distance from the major road are all required to obtain substantial benefits. The largest effect of greening on predicted tranquillity was found to be the size of city squares that were surrounded by buildings with a major road adjacent to one side. Excellent *TR* results were predicted at the centre of a large grass covered square of side 1 km (100 hectares) with visual screening of buildings at the boundary. Even a small square of side 32m (0.1 hectares) is predicted to have a "just acceptable" rating. However the situation is significantly different if hard ground is assumed e.g. paving or asphalt surface and where there is no visual screening of buildings. In this case the range of *TR* values is not predicted to exceed 5 ("just acceptable") even for the largest square of side 1600m (256 hectares).

Another case where large benefits of greening were predicted was for a park alongside a long straight main road with buildings on the farside. When these were fully screened from view it was shown that with grass covered ground a distance from the road of just 25m is required before *TR* values are "just acceptable". At a distance of 800m the *TR* value reaches "excellent". In contrast where there is no visual screening of buildings and the ground is acoustically hard the *TR* value is not predicted to be "just acceptable" even at the large distance of 800m. Note that where a natural noise barrier (or manufactured barrier screened from view with vegetation) was introduced into this situation tranquillity ratings were increased substantially and were predicted to be "fairly good" even at the closest distance of 5m behind the barrier. At a distance of only 300m the *TR* value was "excellent".

Smaller benefits from greening emerged for other scenarios e.g. adjacent to residential roads and in shopping streets unless there was a substantial grass verge of over 100m. In these cases sufficient screening of buildings and large distances from the road can be considered impractical solutions.

Acknowledgement

This project has been funded by the Bradford Centre for Sustainable Environments in the Faculty of Engineering and Informatics at the University of Bradford.

References

[1] G. R.Watts, R. J. Pheasant: Tranquillity in the Scottish Highlands and Dartmoor National Park – The importance of soundscapes and emotional factors. Applied Acoustics 89 (2015) 297-305.

[2] K. C. Lam, K. C. Chau, P. K. Chan: Characterizing natural soundscapes and understanding human response to human-caused noise in a Hong Kong country park. Proc. 153rd Meeting of Acoustical Society of America, Salt Lake City, Utah: USA, June 2007.

[3] G. R.Watts, A. Miah, R. J. Pheasant: Tranquillity and soundscapes in urban green spaces - predicted and actual assessments from a questionnaire survey. Environment and Planning B: Planning and Design 40(1) (2013) 170–82.

[4] G. R. Watts, R. J. Pheasant, K. V. Horoshenkov: Validation of tranquillity rating method. Proc. Institute of Acoustics and Belgium Acoustical Society, Noise in the Built Environment, Ghent, April 2010.

[5] Department of Transport and Welsh office: Calculation of Road Traffic Noise. HMSO, London, 1988.

[6] P. G. Abbott, P. M. Nelson: Converting the UK traffic noise index LA10,18h to EU noise indices for noise mapping. Project Report PR/SE/451/02, TRL Ltd, Wokingham, UK, 2002.

[7]http://www.ergotron.com/Portals/0/literature/whitePapers/english/ergonomics_arms_data.pdf

[8] http://www.cambridgeincolour.com/tutorials/cameras-vs-human-eye.htm

[9] L. Huddart: The use of vegetation for traffic noise screening. Research Report RR238, TRL Ltd, Wokingham, UK, 2002.

[10] G. R. Watts, R. J. Pheasant, K. V. Horoshenkov: Towards "natural" noise mitigation for surface transport. New Zealand Acoustics 24, 1 (2011) 13-19.