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Measured light vehicle noise reduction by hedges

Timothy Van Renterghem [a,*], Keith Attenborough [b], Manuel Maennel [c], Jerome Defrance [d], Kirill Horoshenkov [e], Jian Kang [f], Imran Bashir [b], Shahram Taherzadeh [b], Beate Altreuther [c], Amir Khan [e], Yuliya Smyrnova [f], Hong-Seok Yang [f]

[a] Ghent University, Department of Information Technology, Sint Pietersnieuwstraat 41, B-9000 Gent, Belgium
[b] The Open University, Department of Engineering and Innovation, Walton Hall, Milton Keynes MK7 6AA, UK
[c] Müller-BBM, Robert-Koch-Straße 11, 82152 Planegg, Germany
[d] Centre Scientifique et Technique du Bâtiment, 24 rue Joseph Fourier, F-38400 Saint-Martin-d'Hères, France
[e] School of Engineering, University of Bradford, Bradford BD7 1DP, UK
[f] School of Architecture, University of Sheffield, Western Bank, Sheffield S10 2TN, UK

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ABSTRACT

The acoustical effects of hedges result from a combination of physical noise reduction and their influences on perception. This study investigates the physical noise reduction so as to enable estimation of its relative importance. Different in-situ methods have been used to measure noise shielding by hedges. These include a statistical pass-by experiment where the real insertion loss of a hedge could be measured, three controlled pass-by experiments using a reference microphone at close distance, and transmission loss measurements using a point source. Thick dense hedges are found to provide only a small total A-weighted light vehicle noise reduction at low speeds. Measured insertion losses range from 1.1 dBA to 3.6 dBA. The higher noise reductions are found to be associated with an increased ground effect.

1. Introduction

A hedge (or hedgerow) is a row of closely planted shrubs or low-growing trees. Hedges are most often used as a way of defining land property boundaries or as windbreaks. Hedges may consist of single species or a mixture of species. A wide variety of shrubs and trees, both coniferous and deciduous species, can be used to form hedges, adding to their wide applicability.

When looking at the acoustical effects of hedges, two aspects can be distinguished.

On the one hand, leafs, twigs, branches and trunks can provide physical noise shielding. Noise reduction is obtained primarily by multiple scattering processes, causing sound energy to diverge away from a straight propagation path between source and receiver. Damped leaf [1,2] and branch [3] vibrations, and general visco-thermal absorption effects at leaf surfaces, may contribute to the acoustic shielding as well. In addition, ground effects can be enhanced [4] due to the presence of a highly porous decomposing plant litter layer above the soil in which the hedge is planted. Although hedges are typically of finite depth, depending on the source-receiver distance and source and receiver heights, the specular soil reflection spot could be located in the zone below the hedge. Furthermore, hedges may have an important influence on the local wind profile. As a result, refraction of sound by wind in the direct vicinity of the hedge might be altered.

The widely used ISO 9613-2 model [5], for predicting outdoor sound propagation, includes a correction for shielding by vegetation. The only predictor in this ray-tracing based model is the distance travelled through the vegetation under worst case i.e. downward-refracting conditions. Only when the (slightly bent) sound ray interacts for at least 10 m with the vegetation, a noise attenuation of 1 dB is predicted for the 1 kHz octave band. When the interaction path length exceeds 20 m, 0.06 dB/m is proposed. However, no distinction is made between the type of vegetation (e.g. a strip of forest, a shrub zone, or hedges). This means that for a common hedge thickness of 1 m or 2 m, a zero effect is predicted, which is however doubtful. Other vegetation related parameters that have been shown to play a role like biomass density [6,7], leaf size [6–8], and leaf orientation [9] are not considered in this engineering model. The importance of these parameters in case of hedges remains, however, a question.

On the other hand, it is known that hedges have a strong impact on the visual setting. The audio–visual interaction, in general, could be important when assessing e.g. loudness or noise annoyance. Two main effects play a role relating to hedges, namely visibility of the source and the mere presence of green elements.

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* Corresponding author. Address: Ghent University, Department of Information Technology, Acoustics group, Sint Pietersnieuwstraat 41, B-9000 Gent, Belgium. Tel.: +32 9 264 36 34.

E-mail address: timothy.van.renterghem@intec.ugent.be (T. Van Renterghem).

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Aylor [10] concluded that as long as the source of sound can be seen, reduction in the visibility of the source is accompanied by a reduction in apparent loudness. However, when the source is completely obscured by a barrier, this effect reverses, i.e. the apparent loudness increases [10]. Similar conclusions were found by Watts et al. [11]. Vegetation, (fully) visually screening the road traffic, seemed to increase noisiness compared to transparent vegetation. The latter was explained by erroneous expectations by the test subjects [11]. Visual attractiveness of vegetation did not appear to be relevant in the study of Watts et al. [11]. Hedges that made passing vehicles invisible resulted in significantly less noise annoyance [12]. At higher noise levels this effect seemed to be even more pronounced [12].

In many other experiments, visible vegetation has been shown to have a positive influence on noise perception. Attractiveness of courtyards, strongly linked to the presence of vegetation, was shown to be an important modifier when benefiting from the quiet side effect related to road traffic noise [13]. Non-human sounds like road traffic noise were perceived as less unpleasant and less stressful when the visual setting was less urban or greener [14]. Visible greenery was shown to significantly reduce noise annoyance at home [15]. Natural features present in the visual field were shown to be relevant predictors when assessing tranquility [16]. In another study [17], ninety percent of the subjects believed that hedges strongly reduce noise levels, most likely by implicitly including perceptional aspects in their answers. In this same experiment, view on hedges and vegetation resulted in clearly different electroencephalograms (EEG) at the subjects when submersed in a road traffic noise dominated soundscape, compared to subjects with a (full) view on the traffic noise source. It was therefore concluded that landscape plants provide excess noise attenuation effects through the subjects' emotional processing [17].

The acoustical effect of hedges is therefore expected to be a combination of both physical and perceptional aspects. However, their relative importance is unknown. To contribute to this discussion, the physical noise shielding of hedges is assessed by measurements in this paper. To the authors' knowledge no systematic, scientific studies have been reported yet on this subject.

2. Measurement approaches

Measurements near hedges have been performed independently by different researchers, employing various measurement methodologies. As the focus is on road traffic noise, real-life road traffic noise cases were included in this study. The measurements were performed near rather dense hedges, with thicknesses ranging from 1.3 to 2.5 m, having heights from 1.6 m to 4 m. An overview of the measurement approaches and basic hedge information is given in Table 1.

Four measurement methodologies have been applied. In a statistical pass-by experiment, a sample of real traffic passing in front of the microphone(s) was taken. These measurements were performed at the same location before and after the removal of a hedge. Variability in source emission cannot be controlled as different cars (having their own sound radiation pattern) drive by in presence or absence of the hedge. However, a statistically sufficient number of vehicles were measured in each case, so that single cars lose their importance in the final result. Exact vehicle speed was measured. Clearly, such measurements give an overall picture of what can be expected in realistic traffic conditions.

In the controlled pass-by experiments, the same cars drove along both the microphone located behind the hedge, and the reference microphone. Only passages at constant speed, and when the acoustic measurements were undisturbed by other noise sources, were retained. This approach should lead to limited variability in source emission characteristics.

In case of transmission loss measurements, there is full control over the noise source. Although a point source is a well-defined concept, realistic road traffic noise emission patterns are more complex [18].

The statistical pass-by experiment at Wolfratshausen is a true insertion loss (IL) measurement. Microphone positioning was exactly the same in presence and absence of the hedge. In between these measurements, the hedge was removed. The controlled pass-by experiments in Grenoble and Milton-Keynes involved a reference microphone, positioned at the same distance relative to the road as the microphone positioned behind the hedge. Both microphones were positioned at close distance to ensure the same noise emission characteristics of the passing vehicle.

In these measurements, the ground-reflected sound path will interfere with the direct sound path transmitted through the hedge. Such interference effects are strongly dependent on the exact source-receiver geometry. For the measurements at Wolfratshausen, the ground effect should cancel out due to the same microphone positioning in absence and presence of the hedge. A low wall being present in both situations would further limit the importance of soil reflections. For the transmission loss measurements in Derbyshire, the microphones at the source side and opposite side, relative to the hedge, were placed at the same distance relative to the point source, and at the same height. When subtracting these sound level spectra, the ground effect should cancel

Table 1
Some basic properties of the different hedge measurements performed.

Type of experiment	Noise source	Ground effect included in measurements?	Spectral data?	Hedge species	Hedge thickness (m)	Hedge height (m)	Location	Month of measurement
Statistical pass-by	Road traffic noise	Partly cancelled	No	Spruce (*Picea* sp.)	2	4	Wolfratshausen, Germany	October and November
Controlled pass-by	Road traffic noise	Yes	Yes	Laurustinus (*Viburnum tinus*)	1.8	2.6	Grenoble, France	February
				Hawthorn (*Crataegus monogyna*)	1.9	1.6	Milton-Keynes, UK 1	October
				Horn been (*Carpinus betulus*)	2	1.9	Milton-Keynes, UK 2	October
Transmission loss	Point source	Yes	Yes	Yew (*Taxus baccata*)	1.6	2.2	Derbyshire, UK 1	September
				Beech (*Fagus sylvatica*) 1	2.2	3.9	Derbyshire, UK 2	September
				Beech (*Fagus sylvatica*) 2	1.7	2.6	Ilkley, UK 1	August
				Laurel (*Prunus laurocerasus*)	2.5	2.7	Ilkley, UK 2	August