Applied Acoustics 133 (2018) 123–132

Contents lists available at ScienceDirect

Applied Acoustics

journal homepage: www.elsevier.com/locate/apacoust

Time-evolution of sound levels around a roadside building

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ARTICLE INFO

Keywords:
Sound propagation
Diffraction
Building
Measurement
Simulation

ABSTRACT

The time evolution of the sound impact due to single cars driving along a road was evaluated at seven receivers in front of and behind a road-side building. The sound impact was measured in the field and around a scale model of the building in a laboratory. In addition, two calculation methods were applied: a complex numerical finite-difference time-domain model based on the Euler equation and a simple ray-based calculation according to the ISO 9613-2 standard. On the backside of the building where sound waves only arrive by diffraction, the differences between the four methods are disappointingly large. Some of the discrepancies can be explained by diverse assumptions and boundary conditions which go along with the individual methods. However, a major disagreement largely remains an open problem, namely the magnitude of the drop of the sound level in the acoustical shadow of the building. It is fairly strong in the scale-model measurements and the Euler model simulations on the one hand, but rather weak or even not existing in the field measurements and ISO 9613-2 calculations on the other hand.

1. Introduction

Road traffic noise is a major concern in many European countries and worldwide. Most traffic-noise prediction procedures and national standards only provide energy-equivalent average sound levels L_{eq} on the base of traffic parameters for roads and railway lines. However, the assessment should also be interpretable with respect to possible noise effects on human beings such as health impairments, sleeping disturbances or annoyance. Conventional exposure-response relationships rely on average sound levels (Miedema and Voss [1]; Miedema and Oudshoorn [2]; Lercher et al. [3]). More recent studies also consider event-related noise parameters which characterize the time evolution of sound levels like the number of events, the maximumlevel, the noise duration or the sound-level change rates (e.g. Basner et al. [4]). Elmenhorst et al. [5] found that the maximum level of an event and the maximum level rise are highly significant indicators of sleep disturbances caused by railway noise. For annoyance they found that the L_{eq} alone is not a significant predictor, while the number of events in combination with non-acoustical parameters is significant.

If the vicinity of a road is free of obstacles, the temporal variation of the sound level due to moving vehicles can be easily calculated using analytical formulae (Heimann and Schady [6]). However, buildings and other obstacles lead to reflections and shading. Some sound may propagate through gaps between the obstacles, either directly or by diffraction. This geometry often results in a rather irregular time behaviour of the sound level at receivers between and behind a road-side development. The average sound level, maximum level and maximum change rate are affected by the buildings and thus differ from those in unobstructed situations.

Diffraction is the key process that enables sound to propagate into areas which are shaded by buildings or other obstacles. Diffraction theory has been made progress during the 1970ies and 1980ies (McNamara et al. [7]). Numerical propagation models that solve the wave equations explicitly account for diffraction (e.g. propagation over a barrier; Salomons [8]; Heimann and Blumrich [9]). However, ray-based models often use simplified heuristic diffraction models. These calculate the diffractive attenuation based on the difference between a diffracted ray from source to receiver around and over an object and a direct ray between source and receiver neglecting the object. These models can also be described as detour models. A simple detour approach is implemented in the ISO 9613-2 standard [10] to calculate sound levels in the acoustical shadow of screens and buildings. A related but slightly more complex diffraction model is described in the Harmonoise project (Salomons et al. [11]). It is a detour model which calculates the diffracted ray based on Fresnel zones. A more sophisticated approach was introduced by Wei et al. [12].

Sound propagation over a single building was investigated by Alberts II et al. [13]. In another paper Remillieux et al. [14] studied the sound propagation at an isolated building not only in the field, but also compared the results with numerical simulations. In both papers

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https://doi.org/10.1016/j.apacoust.2017.12.011
Received 31 July 2017; Received in revised form 14 November 2017; Accepted 11 December 2017

artificial sources of impulsive broadband sound were used. However, the time-history of sound levels according to moving sources (e.g. cars) were not addressed.

The present study investigates a real situation with a roadside building with four different methods: sound from moving sources is studied by (1) field measurements, (2) laboratory scale-model measurements, (3) advanced numerical sound propagation modelling, and (4) engineering-type sound prediction. The resulting sound level variations in space and time are compared and deviations are discussed. So far, such a setting has not been in the focus of previous publications, although dynamic simulations of traffic sound in built-up areas were recently published. Most of these papers aim at probability statistics of sound levels in urban areas with many buildings (e.g. Wang et al. [15], Walker et al. [16]) and therefore do not really compare with the present study. Hou et al. [17] discuss measured and simulated sound levels at a single roadside building. However, the building in their study is of rather complex shape and only two of totally six measuring points are located outdoors, one near the road and another one on the backside of the building. Unfortunately, time-series are only shown in rather coarse resolution (1 s) and for the point near the road and two indoor points. Temporal variations of the sound level are due to fluctuating traffic rather than due to shading by the building.

2. Case study

2.1. General situation

The study considers a single two-storey building with a saddle roof located close to a two-lane state road (St 2068) about 20 km west of Munich/Germany (Fig. 1). The building belongs to the Oberpfaffenhofen site of the German Aerospace Center (DLR) and is used as a kindergarten. The detailed geometry of the building and its position relative to the road is shown in Fig. 2. Photos are provided in Fig. 3. They show that the building (A) is not symmetric. In particular, there is a one-storeyed annex (B) and a small separate flat-roofed housing of a natural-gas distributor (C) on the northern side. The nearest facade of buildings outside the area shown in Fig. 2 is about 55 m to the southeast (cf. Fig. 1).

The building complex A-B-C stands in a grass garden, but its immediate surrounding is paved. Between building and road there is a green strip with bushes and a few single trees. The road is 7 m wide and paved with asphalt. The speed limit is 70 km/h. On the side of the building, the road is accompanied by a paved pedestrian/bike way. Except the state road, there are other potential sources of noise: a suburban railway line in the west (closest distance 320 m), the federal motorway A96 in the north (closest distance 620 m), and the Special Airport Oberpfaffenhofen (ICAO-code: EDMO) in the east (closest distance to the runway 700 m).

2.2. Field measurements

Acoustical measurements were performed during the weekend 12–13 March 2016. The evaluation was restricted to selected drive-by events of vehicles during the second half of the weekend nights (11/12, 12/13 and 13/14 March). Extraneous noise is minimized at this time. The kindergarten is closed on weekends and the airport is not operating

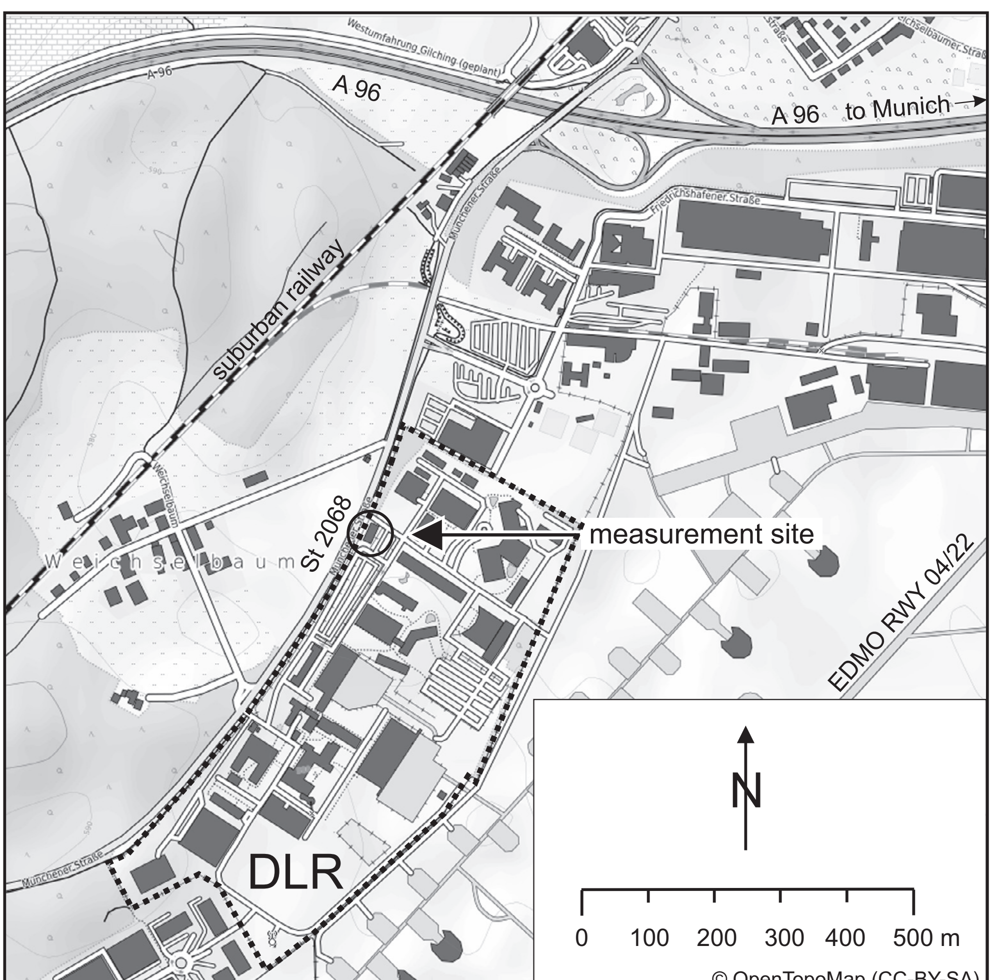

Fig. 1. Topographical map showing the measurement site (encircled) within the DLR Oberpfaffenhofen research campus (enclosed by dotted line) and its vicinity with the state road St2068, the motorway A96, the suburban railway and the airport runway (RWY).