The acoustic basis of the NORAH field studies

Ulrich MÖHLER[1], Manfred LIEPERT[1], Maximilian MÜHLBACHER[1], Maria KLATTE [2],

Berthold VOGELSANG [3], Georg THOMANN[4]

[1] Moehler + Partner Consulting Engineers, Munich, Germany

[2] Technical University of Kaiserslautern, Kaiserslautern, Germany,

[3] Ministry for Environment, Energy and Climate Protection of Lower Saxony

[4] Office of Nature and environment, Graubuenden, Switzerland

ABSTRACT

The acoustic impact of road traffic, rail traffic and air traffic noise was to be determined for about 22.000 addresses of the modul "Disturbance of quality of Life", for about 900.000 addresses of the modul "Health" and about 1.300 addresses of the modul "primary school children". As common descriptor for the noise pollution, the average sound level and the maximum sound level were selected. The point of immission for the determination of exposure to noise caused by road and rail traffic was in front of the facade exposed to the highest noise level at a given address and for aircraft noise in the center of the building. In some cases, the sound levels were determined in dependence of the orientation of bedrooms and living rooms in relation to the source of traffic noise. In addition to the outdoor sound levels given above, the indoor sound levels were estimated for the addresses investigated based on answers about the habits of opening and closing the windows. The time periods day (06–18h), evening (18–22h), night (22–06h), 24h – which are also being used in legislation – were applied as reference times for calculating average sound levels. In addition, depending on the given task, constant sound levels were determined for other time slots. The uncertainty of the results of calculations was quantified in the NORAH study to allow an illustration of its effects on the results of the study and to thus increase transparency of the survey as uncertainty can affect the relationship between exposure and effect. For this purpose, detailed step-wise error estimations were carried out separately for the types of sound source and the essential factors of sound emission and sound propagation.
Keywords: Aircraft Noise, Road Traffic Noise, Railway Noise,

1. INTRODUCTION

In the context of the NORAH studies, the exposure to traffic noise for the 3 modules in the NORAH study (module 1 "Disturbance and quality of life", module 2 "Health" and module 3 "Effects of chronic aircraft noise pollution on cognitive performance and quality of life of primary school children") was to be determined. The aim was to calculate, as realistically as possible, the individual noise levels for each participant in the study in their respective housing situation, inside and outside their homes, separated into sounds associated with aircraft, road and rail traffic.

The study area for modules 1 and 3 was the region around the Frankfurt/Main airport that is exposed to constant sound levels ≥ 40 dB(A) and the corresponding areas around Cologne/Bonn, Stuttgart and Berlin/Schönefeld airports. The area investigated in study module 2 extended across the entire Darmstadt administrative district in the State of Hessen and parts of the State of "Rheinland-Pfalz". Study module 1 was to determine the levels of noise pollution in the region of Frankfurt airport for approx. 22.000 addresses and for 22.200 addresses in the areas of the airports used for comparison, Cologne/Bonn, Stuttgart and Berlin/Schönefeld.

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[1] info@mopa.de
[2] klatte@rhrk.uni-kl.de
[3] berthold.Vogelsang@mu.niedersachsen.de
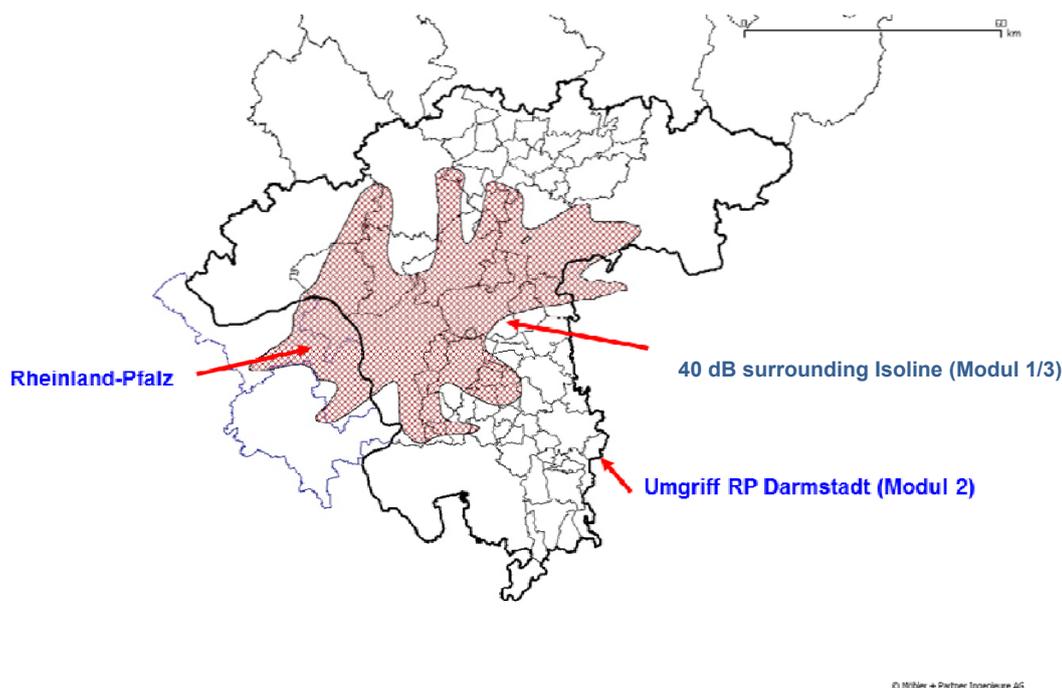[4] georg.thomann@anu.gr.ch

Figure 1 – Area of investigation in the environment of Frankfurt airport

Noise pollution levels were to be determined for approx. 863.200 addresses in study module 2 and for approx. 1.300 addresses in study module 3 (1)

2. METHODS OF CALCULATION

2.1 Immission points

The point of immission for the calculation of noise exposure caused by road and rail traffic was in front of the facade exposed to the highest noise level at a given address and in the centre of the building for aircraft noise. Study modules 2 and 3 obtained information on the orientation of subjects' bedrooms and living rooms in relation to the source of traffic noise from data collected in interviews; the sound levels were related to the facade in question. In addition to the outdoor sound levels given above, the indoor sound levels were estimated for the addresses investigated in the case-control study in module 2 based on answers about habits related to the opening of the windows; corrections of the estimates were made depending on the position of the window. Detailed data on the acoustic properties of external elements of the buildings were collected by the field personnel in association with the substudy "Blood pressure monitoring" in study module 2 and in study module 3. Based on this data indoor sound levels were additionally estimated for the above mentioned 1.300 addresses in study module 3.

2.2 Acoustic Characteristics

Noise pollution was characterized using both the average sound level for different time periods and the maximum sound level. The time periods day (06–18h), evening (18–22h), night (22–06h), 24h – which are also being used in legislation –were applied as reference times for calculating average sound levels. In addition, depending on the given task, sound levels were determined for other time slots. Thus the thereby determined noise pollution should refer to the time period during which the interviews were carried out. This covered the years from 2010 to 2014 in the study modules 1 and 3. For study module 2, noise pollution experienced by the subjects also had to be assessed for previous years, going back to 1996.

2.3 Aircraft Noise

Average and maximum sound levels caused by aircraft noise were determined in accordance with the guidelines for calculations for noise abatement zones AzB (2). The basis of the data collection system was insufficient for the scope that needed to be considered in study module 2. Additionally the required data were not available for all study years. The requirements of the scope of the study area and of the documentation on past years were fulfilled through the direct use of individual radar data. However, this required the development of a new calculation procedure that can separately process the flight paths of individual flights recorded by the flight safety radar. Various options for considering different parts of the radar data (position x, y, z and velocity v from FANOMOS data) were assessed and comparative calculations were carried out for this procedure. These different options were then verified by comparing the calculated average sound levels with the values of measurements of monitoring stations.

Table 1 – Mean (M) and standard deviation (SD) of the difference between measurement and calculation on stationary measurement points in dB (number of measurement points N = 21)

	x,y from radar tracks / z;v from AzB	x;y;z from radar tracks / v from AzB	x;y;z from radar tracks with landing / v from AzB	x;y;z;v from radar tracks
	FANOMOS day [dB]			
M	0,3	0,7	0,4	0,4
SD	0,9	1,0	0,9	1,0
	FANOMOS night [dB]			
M	0,6	1,0	0,7	0,7
SD	0,8	0,8	0,8	0,8

As can be seen from the table, the results are esp. with respect on the standard deviation are equivalent. The procedure that was finally decided on (x;y;z;v from radar tracks) showed the most easy implementation. The input data for the aircraft noise calculations were made available by the German flight safety operator, DFS, for the required years given above.

2.4 Road Traffic and Railway Noise

The data required for road traffic was obtained from traffic counts and the data for rail traffic was derived from information provided by the Federal Railway Authority and the German Railway environmental department. The reduction in sound levels along the path of propagation between the source of the sound and the immission site is determined based on a digital landscape model that included both the landscape and the footprints of buildings. Additional sources of information were used to determine the position of noise barriers and walls along roads and railway tracks. The average sound levels for road and rail traffic noise were determined based on the methods for calculation VBUS (3) and VBUSCH (4) used for EU noise mapping in Germany. There are no standard methods for calculating the maximum sound levels for road and rail traffic noise. Therefore methods for estimating maximum sound levels were derived for this purpose. The calculated data were stored in databases. The results of these calculations were subjected to a plausibility check and corrections were made, if necessary, before the data were released to the study modules.

2.5 Uncertainty

Acoustic parameters generally incorporate uncertainties and also random errors, irrespective of whether these are sound parameters that have been calculated or measured. Uncertainty due to the measurement already arises from the uncertainty associated with the measuring devices, but is then increased by the surrounding conditions during measurement, i.e. (generally stochastic) variations in emission, weather conditions and extraneous noise. In contrast, calculations are based on acoustic

models that approximate the real situation. In both cases, determination of noise exposure always incorporates uncertainty, even if this is not always stated explicitly. This uncertainty was quantified in the NORAH study to allow an illustration of its effects on the results of the study and to thus increase transparency as uncertainty can affect the relationship between exposure and effect. For this purpose, detailed step-wise error estimations were carried out separately for the types of sound source under observation and the essential factors of sound emission and sound propagation. In summary, the combined standard uncertainty is revealed to be between 3 and 5 dB. The effect of the uncertainty on the results of the exposure-effect relationship was assessed based on the example of study module 3. This revealed that the inclusion of the uncertainty associated with exposure to traffic noise in the interdisciplinary analyses does result in an increase in overall uncertainty, but that the effects on the course of the exposure-effect-relationship (5,6) are small.
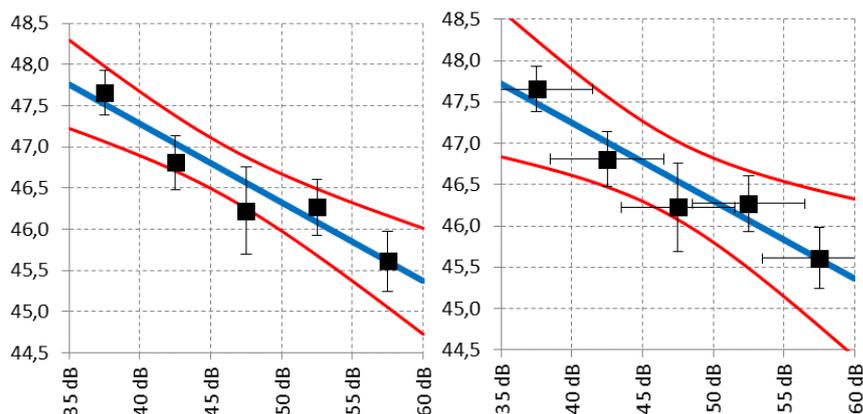

Figure 2 – Relation between the variable „text comprehension" and average noise level caused by aircraft noise around schools without (left figure) and with (right figure) consideration of uncertainty of noise calculation; mean values in level classes shown as black boxes and extended uncertainty as error bars; blue line: best fit; red lines: 95% confidence interval

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