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Socio-Acoustic Survey of Sound Quality in Dwellings in Norway

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ABSTRACT

An extensive socio-acoustic survey has been performed in Norway. Based on field measurements of sound insulation in 600 dwellings, a questionnaire was sent to the residents. 702 respondents evaluated the sound quality of their homes, 97% of which were apartments in multi-unit houses. The range in the field measurement results allowed for establishment of exposure-effect relationships for annoyance for both impact and airborne sound insulation. The correlation between subjective evaluation and measured sound insulation descriptors showed interesting results. For airborne sound insulation the standardized level difference $D_{nT,w}$ showed best correlation in most cases; the low-frequency spectrum adaptation term (including 50 Hz) did not improve the correlation except in relation to music with bass and drums. However, for impact sound the results were strongly in favor of the low-frequency spectrum adaptation term (including frequencies down to 50 Hz); without this there was no correlation with subjective response. The outcome of the project give grounds for choosing sound insulation limits based on annoyance.

Keywords: Sound insulation, impact sound, exposure-effect relationship

1. INTRODUCTION

In 2015 a social survey of noise conditions in dwellings was carried through in Norway [1], aiming to assess whether present sound insulation and noise level requirements are adequate or in need of revision. The sound insulation measurements are done in dwellings from 2002-2015. Questionnaires were sent to 3849 persons living at the actual addresses and 702 completed questionnaires were received.

Airborne and impact sound insulation was measured between dwellings in horizontal and vertical direction. From the measured data it was possible to derive both normalized and standardized single-number results, without or with the low-frequency spectrum adaptation terms [2, 3].

The exposure-effect relationship curves from this survey does not represent the average annoyance of the population as a whole, but give a solid basis for evaluation of sound insulation and noise level limits where they apply.

2. REGULATIONS ON SOUND INSULATION IN NORWAY

Structural requirements for new buildings are specified in the Regulations on technical requirements for building works (TEK10) [4]. TEK10 regulates requirements in form of functional requirements, and contains a reference to the Norwegian standard NS 8175 [5]. The criteria for acoustic conditions are divided into four classes (A to D). Class C represents the minimum limit value to fulfil the functional requirements in TEK10, and the current requirements for airborne and impact sound pressure levels are given in table [1]. Except for a new, and more lenient, sound limit for balcony access blocks with windows directly towards the balcony that was introduced in 2008, the limits for airborne and impact sound insulation have not changed since 1997.

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Table 1 – Limit values for sound insulation in Norway , class C, NS 8175:2012

Airborne sound insulation	Impact sound insulation	Comments
$R'_w \geq 55$ dB	$L'_{n,w} \leq 53$ dB	All dwellings, between dwellings and between dwelling and corridor/public hallway etc
$R'_w \geq 45$ dB		Between gallery and rooms with windows directly to the gallery

3. MEASURED SOUND INSULATION DATA

The survey is based on more than 900 different field measurements carried out in 600 dwellings from 2002-2015. In projects with several equal multi-unit houses, residents in all houses received the survey, assuming the same building performance in all buildings.

3.1 Distribution of measurement results.

To obtain statistically reliable results, a good spread in the sound insulation and noise source levels is essential. Figure 1 and 2 show the distribution in measurement results for weighted apparent sound reduction index, R'_w, and the weighted normalized impact sound pressure level, $L'_{n,w}$, respectively. Results are divided into light and heavy constructions in order to assess their perceived sound qualities separately. As expected, the heavy constructions are better than the light ones both for airborne and impact sound insulation.

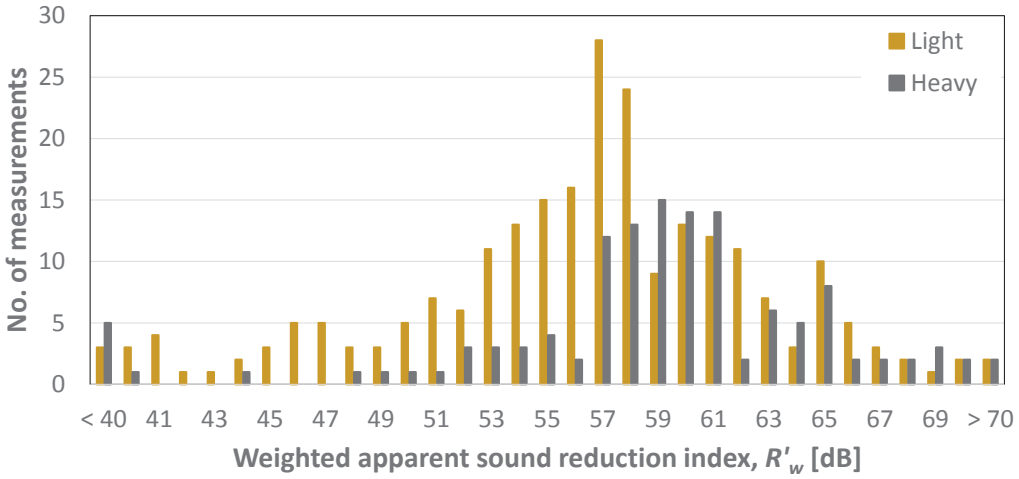


Figure 1 – Distribution of field measurements for sound reduction index, R'_w.

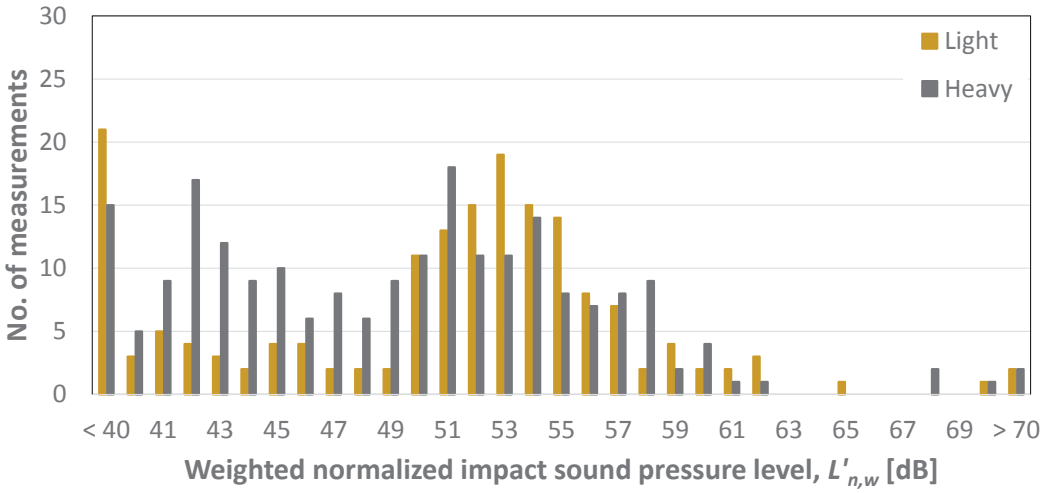


Figure 2 – Distribution of field measurements for impact sound pressure level, $L'_{n,w}$.

The field measurement results vary over a relatively wide range, even though all dwellings are fairly new, and supposed to be built in accordance with today's requirements. The range in the field measurement results allow for establishment of exposure-effect relationships for annoyance for both impact and airborne sound insulation.

3.2 Alternative sound insulation parameters

There are alternative parameters that can be used when evaluating the experience of sound and sound insulation. On both national and international levels the inclusion of low frequencies (below 100 Hz) is discussed. The parameters of interest are:

For airborne sound insulation: R'_w , $R'_w + C_{50\text{-}5000}$, $D_{nT,w,}$ and $D_{nT,w} + C_{50\text{-}5000}$

For impact sound insulation: $L'_{n,w}$, $L'_{n,w} + C_{I,50\text{-}2500}$, $L'_{nT,w}$ and $L'_{nT,w} + C_{I,50\text{-}2500}$

Almost all of the sound measurements include results down to 50 Hz, which makes it possible to evaluate the alternative parameters. To explore which is best suited to describe the perceived noise levels, the results form noise measurements are put together with the respondents' evaluation, and an extensive amount of regression analysis has been conducted.

4. QUESTIONNAIRE AND RESPONDENTS

4.1 Questionnaire

The questions used in social surveys on noise problems are very important for the quality of the results. The way in which such questions are asked, and the wording of the possible answers should follow the recommendations in ISO/TS 15666 [6]. The standard contains an Annex B with the recommended wordings in several other languages, including Norwegian as used in this investigation. The questions and possible answers are of this form: "Thinking about the last 12 month, when you are at home, how much are you annoyed of noise from … ? Not at all – Slightly – Moderately – Very – Extremely".

The questionnaire consisted of 35 different questions in addition to background information about the respondents. The questions can be grouped as:

- annoyance score concerning noise inside and outside of the dwelling
- noise sensitivity
- annoyance score concerning special noise sources (service equipment, neighbours, road traffic etc.)
- restrictions on own behavior not to disturb others
- willingness to pay for a better sound insulated dwelling

4.2 Respondent groups and category of dwellings

Questionnaires were sent to 3849 persons living at the actual addresses where the measurements were done, and 702 completed questionnaires were received. This is the *main respondent group*. In addition, questionnaires were also sent to three campus sites, about 1500 students, to enhance data regarding small apartments. 386 completed questionnaires where received from the *student respondents*. For the latter group, sound insulation were calculated based on the known constructions employed, as no sound measurements were available.

The focus has been on multi-unit houses, and 97 % of the addresses in this survey are apartments in multi-unit houses, 1 % is row houses, 1 % is student studios and 1 % is single-unit dwellings. Table 2 shows the distributions of number of rooms for all dwellings in the main group.

Table 2 – Main respondent group and their category of dwelling

Number of rooms (bedroom and living room)	Distribution
1-room apartment	4,2 %
2-room apartment	14.7 %
3-room apartment	44,1 %
4-room apartment	31,7 %
5-room or more	5,3 %

5. RESULTS AND RECOMMENDATIONS

5.1 Findings from the questionnaire

This survey confirms that noise is a significant problem for a lot of people, as around 65 % of the respondents are annoyed by noise to some extent by one or several noise sources, see Figure 3.

It was not within the scope of the project to evaluate traffic noise specifically, so noise exposure levels from traffic have not been correlated with the responses obtained. However, since multi-unit houses are in general in densely populated areas, there is no reason to believe that the traffic noise level are particularly low. Footfall noise is reported to be comparable and even slightly more annoying than traffic noise as more than 40 % are annoyed to some extent, and 20 % are at least moderately annoyed from these noise sources.

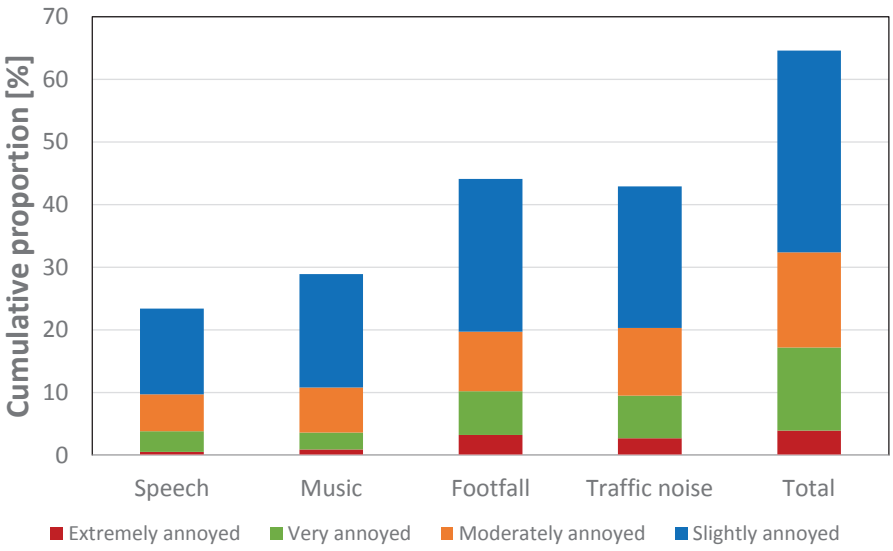


Figure 3 – Annoyance associated with different noise sources.

An additional approach in this study has been to get knowledge of whether people restrict themselves and their behavior to not disturb their neighbours. The results are given in Figure 4. People living in multi-unit houses take especially care when it comes to speech and music.

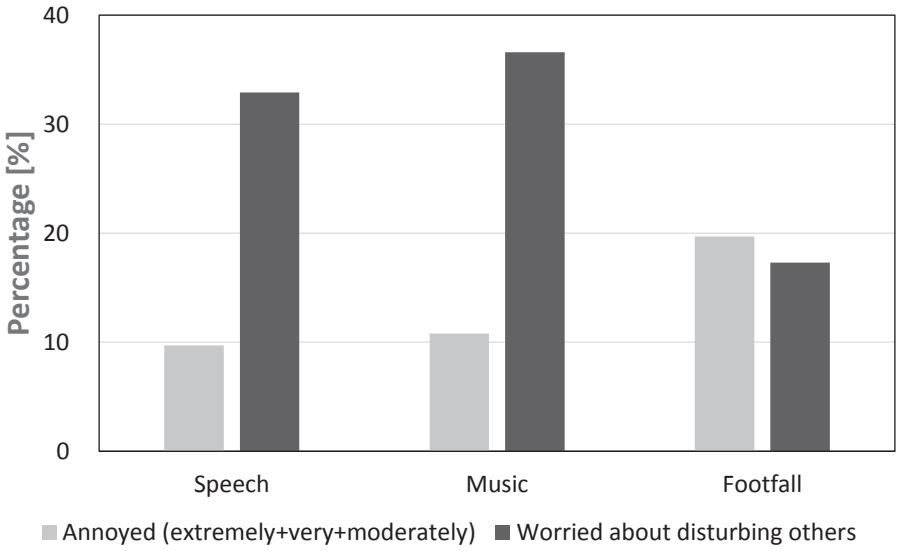
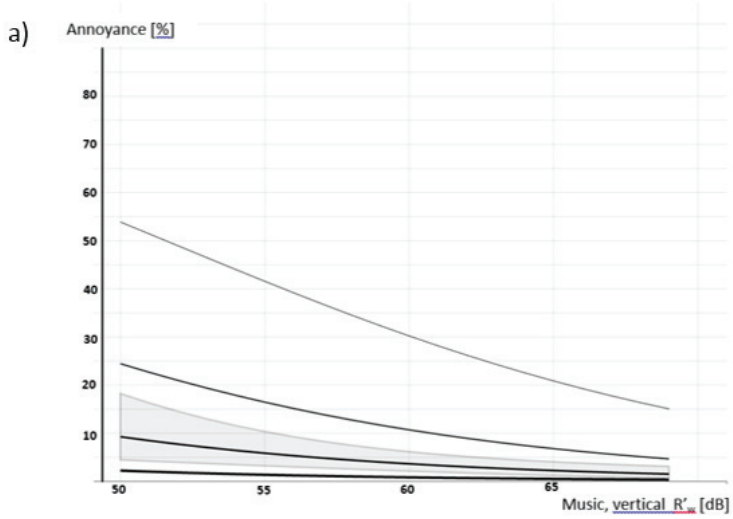


Figure 4 – Noise annoyance in relation to fear of disturbing neighbours.

5.2 Exposure-effect relationship

The correlation between subjective evaluation and measured sound insulation descriptors showed some interesting results. This is further discussed in [1,7,8 and 9]. For airborne sound insulation the standardized level difference $D_{nT,w}$ showed slightly better correlation than the sound reduction index R'_w, in most cases. The low-frequency spectrum adaptation term (including frequencies down to 50 Hz) did not improve the correlation except in relation to music with bass and drums. For impact sound the results were strongly in favor of the low-frequency spectrum adaptation term; without this there was no correlation with subjective response.

The 95 % confidence intervals are in general narrow when the limits are fulfilled and in the adjacent area. However, when the sound insulation quality gets poorer, the confidence interval gets significant broader, as illustrated in Figure 5 a) and b). The curves represent (from the lowest and up) “extremely annoyed”, “extremely+very annoyed”, “extremely+very+moderately annoyed”, and the top curve represent the border between “not at all annoyed” and the sum of those annoyed. The 95 % confidence intervals are illustrated for the “extremely+very annoyed”-curve (grey area).



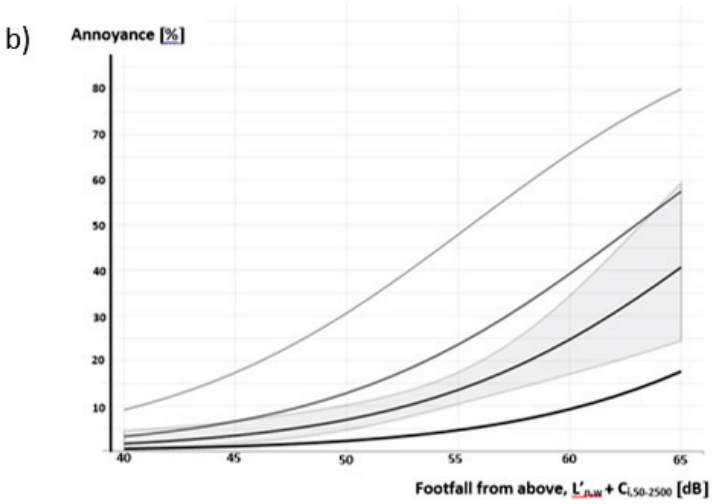


Figure 5 – Exposure-effect relationship for a) vertical sound reduction index, R'_w, and response to annoyance from music; b) vertical impact sound insulation, $L'_{n,w} + C_{i50\text{-}2500}$. The 95 % confidence intervals (grey areas) are illustrated for the "extremely+very annoyed"-curve.

5.3 Willingness to pay

When asked if the regulations on noise and sound insulation are too strict or too lenient, it is an unambiguous response against more lenient limits, as Figure 6 illustrates. Only 1 % of the respondents in the main group, and 2 % in the student group thinks the government's regulations are too strict, whilst 38 % in the main group ant 23 % in the student group thinks today's regulations are too lenient.

Among 702 replies in the main respondent group, more than 50 % were willing to pay an extra monthly amount for a better sound insulated dwelling, as Figure 7 shows. Around 20 % were willing to pay from 6000 to 12000 NOK (600-1200 EUR) per year, for better sound insulation. To the opposite question, less sound insulation for a reduced monthly payment, 86 % replied that this would be out of question; only 10 % would accept lower sound insulation against a lower payment around 12000 NOK per year."

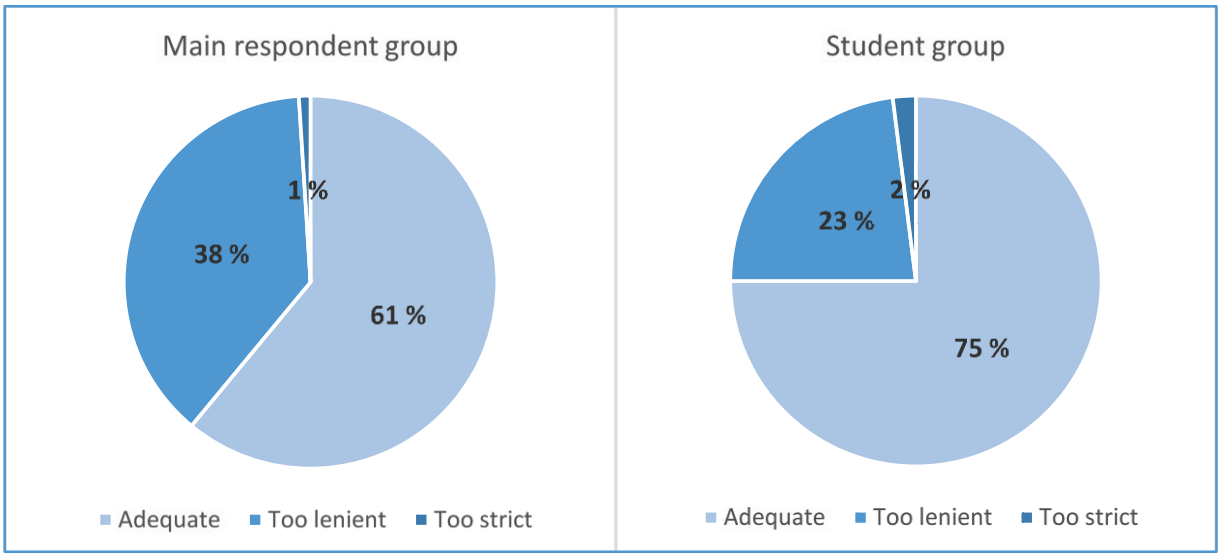


Figure 6 – Respondents reply to the question *What is your opinion about the national sound insulation requirements for dwellings?*

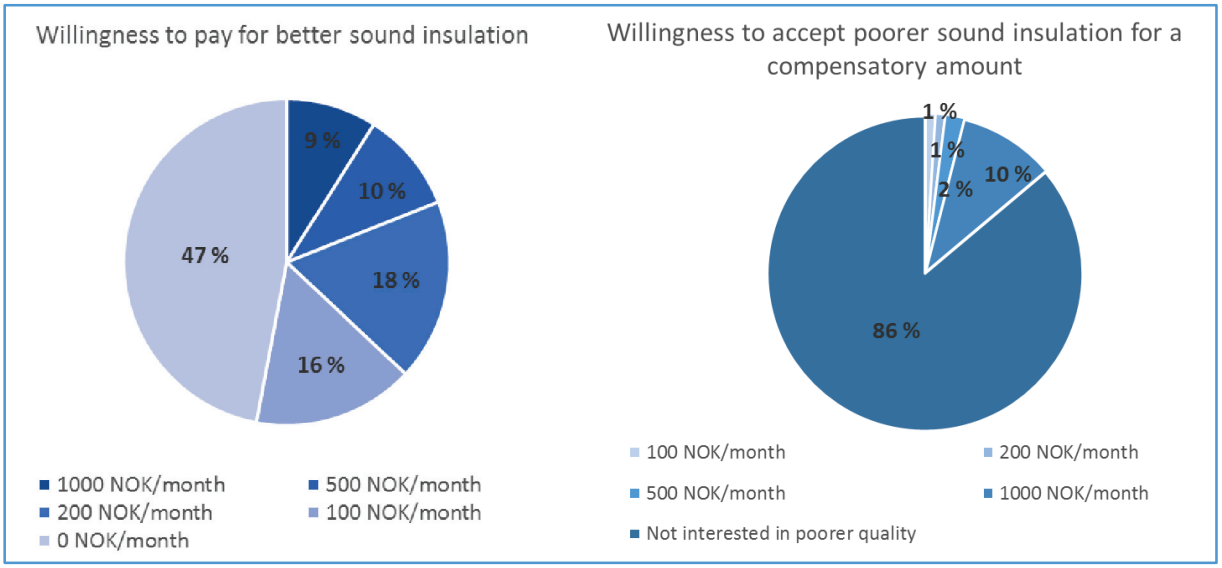


Figure 7 – Willingness to change the sound insulation quality

6. SUMMARY

A new socio-acoustic survey in Norway has provided interesting results concerning the sound insulation in dwellings. Impact noise and traffic noise cause most annoyance, as 20 % reports to be moderately, very or extremely annoyed from these noise sources, which is twice as high as from speech or music. Another interesting aspect is whether one restricts oneself and is worried about disturbing neighbours with noise. As many as 1 out of 3 report that they are worried that airborne noise sources such as TV, music, speech may annoy their neighbours. This indicates that people are likely to limit themselves to a certain extent in consideration of their neighbours for these types of activities.

In general, the survey give grounds for choosing sound insulation limits based on annoyance. There is clear evidence that poor impact sound insulation at low frequencies is a widespread problem, and not only related to lightweight constructions. To have equal requirements, as in equal perceiving of the sound quality, for both airborne sound and impact sound, it is necessary to include the low-frequency spectrum adaptation term for impact sound.

Except for the impact sound insulation, based on the exposure-effect relationship, the results confirm that the noise limits in the Norwegian regulations are at an acceptable level. In this survey, around 60 % of the respondents in the main group find the present requirements adequate. However, almost 40 % of the main respondents find the present limits too lenient, and more than 50 % are willing to pay an extra monthly amount for a better sound insulated dwelling.

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