A comparison of regional noise-annoyance-curves in alpine areas with the European standard curves

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INTRODUCTION

The assessment of the burden of exposure to community noise is primarily based on the effects of noise on annoyance. Although other more specific health effects exist (e.g. cognitive impairment, insomnia, hypertension) the less-specific general expression of community annoyance is assumed to provide the best estimate of the overall effect environmental noise exerts on society (CALM network 2007). Therefore, the European environmental noise directive (END) builts its actual strategy to combat noise upon the assessment of noise effects derived from standard noise annoyance curves (European Noise Directive 2002/49/EC). The claim made is that reliable estimates of community effects can be provided by linking the information of large-scale noise mapping efforts to the standard curves (Miedema & Vos 1998; Miedema & Oudshoorn 2001). This is clearly a step ahead for the implementation of a evidence-based policy at the national and supra-national level. It may, however, be not an appropriate mean to do impact assessments at smaller scales (“it yields a view of the forest, not the trees”, Fidell 1984), such as regional and community levels or at the level of projects subjected to an Environmental Health Impact assessment (EHIA).

The generalized approach to apply the same assessment strategy at all scales is opposed by old and more recent empirical data and discussions which demand a more cautious and context specific approach at smaller scales of impact assessment (Staples 1997; Lercher & Botteldooren 2006).

Meta-analyses have demonstrated large variations in the exposure-annoyance curves at study level and identified a long list of factors which may account for these differences (Job 1988; Fields 1993; Lercher 1996; Miedema & Vos 1999, 2003, Miedema & Fields 2005). Fields et al. (2000) have calculated that the community response differs on average by the equivalent of about 7 decibel in noise exposure and stated later “There is almost no research” into these differences (Fields 2003). It would, however, be important to investigate the determinants of these differences, “because it identifies communities that might be treated differently in noise regulations”. Klæboe et al. (2005, 2006) have observed large variations of the so-called “neighourhood soundscape effect” (values varied between 0 and 17 dBA) by including a neighbourhood maximum difference indicator in the analyses. From another perspective Guski (2004) has started a discussion about time-trends in exposure-response relationships related to aircraft noise. By re-arranging the underlying data of the standard curve he showed that people’s annoyance reactions towards aircraft noise may have changed over time: people today become more annoyed due to aircraft noise than in earlier surveys. This finding was later supported by a systematic review of an extended data base (van Kempen & van Kamp 2005). Also in Korea a recent aircraft survey revealed higher annoyance responses than predicted from the standard curve (Lim et al. 2007). Thus, the basic critique here is that the data on which the standard annoyance assessment is based are outdated (most surveys conducted before 1990) and should be replaced by a more recent data base. A hot debate was triggered by the results of the ANASE-study in the UK, which could also be interpreted as supporting the hypothesis of a change in annoyance due to aircraft noise exposure over time (http://www.dft.gov.uk/pgr/aviation/environmentalissues/Anase/).

Other older and more recent field data from Asian countries increasingly provide consistent evidence that the standard-annoyance curves used in the END may not be equally valid across countries. The specific concern is with the application of the so-called rail bonus. The bonus is supported by the standard curves but has not been found in several carefully conducted noise surveys in Japan and Korea (Yano et al. 1998; Morihara et al. 2004; Lim et al. 2006).

We have reported deviations from standard curves in an alpine region previously (Lercher 1998; Lercher et al. 1999) and have got the opportunity to re-evaluate these results through repeated surveys in the same areas.

METHODS

Area characteristics

Both areas of investigation, the Unterinntal and the Wipptal are part of the most important access route for heavy goods traffic over the Brenner pass which provides the most direct link for central and northern Europe’s traffic to southern Europe. The goods traffic over the Brenner has tripled within the last 25 years and the fraction of goods moved on the road has substantially increased (up to 2/3). The area consist of small towns and villages with a mix of industrial, small business and agricultural activities. The primary noise sources are motorway and rail traffic. Also important are main roads, that link the villages and provide access to the motorway. The areas differed in topography (U versus V valley), meteorology (much wind versus lot of temperature inversions), geographic orientation (north-south versus east-west) and reason for study (EHIA versus research study).

Study characteristic, sample selection and recruitment

All 3 studies were cross-sectional. In the Wipptal (BBT surveys) a phone (N=2,002) and an interview study (N=2,070) were carried out. A pooled sample was created (N=3,630) from both studies (omitting those who participated in both studies: N=442) to get more statistical power and better representation. In the Unterinntal (ALPNAP study) a nearly identical phone survey (N=1,643) was conducted. The participation at the individual level varied between studies (62, 80, 35 % respectively). The research phone study had the lowest participation. Participation at the houshold level was significantly higher (61 to over 80 %).The age range included was slightly broader in the Wipptal (17-85 yrs) than in the Unterinntal (25-75 yrs).

People were contacted by phone based on a stratified, random sampling strategy. The address base was stratified by the use of a Geographic information system (GIS) into areas defined by distance categories to the major traffic sources (rail, motorway, main road), leaving a common „background area“ lying outside major traffic activities and an area with exposure to more than one traffic source “mixed traffic area”. Households were randomly selected from these areas and replaced in case of non-participation. Apart from age selection criteria were sufficient hearing and language proficiency. Excluded were persons living less than one year at this address. Some addresses were not valid, did not have telephone or could not be reached by 3 attempts at different times of the day. While the BBT-interview survey resulted in a balanced sex ratio (983 men and 1,082 women), both phone surveys showed a clear excess of participating women (65 % and 61 %). This reflects the much higher flexibility of the interviewers in terms of appointments compared with the limited random dialing approach on the phone (3 attempts), which favoured women's participation who on average spend more time at home and easier to reach.

Noise exposure assessment

Three groups of traffic noise sources are considered in the noise exposure assessment: Motorway road traffic, road traffic on main roads, and railway traffic. For motorway traffic the yearly average load (light and heavy vehicles) is combined with an average diurnal traffic pattern. Existing traffic frequency data on main roads were supplemented with additional traffic counting. Noise emission by road traffic was calculated on an early version of the Harmonoise source model (Jonasson 2007). In addition, microsimulations of the traffic flow were conducted with Paramics (Quadstone®, www.paramics-online.com) to obtain optimal individual vehicle characteristics (speed and acceleration). Railway noise emission is extracted from a typical day out of several long-term noise immission measurements (one to two weeks at different seasons) at close distance to the source. Noise modeling was carried out with Bass3, which is an extended in-house development of ISO-9613. The model includes up to four reflections and two sideway diffractions (de Greve et al. 2005).

Extensive noise monitoring campaigns were conducted in both areas to check the validity of these simulations against the measurement results. Measurements revealed slightly higher levels – probably due to additional sources resulting from daily human activities not covered in the transportation noise simulations.

In the Wipptal 692 binaural short-term (15 minutes) day-night recordings were conducted in summer (May-July) and winter (October-November) and 10 long-term mono-aural measurements (7-10 days) at selected points and used for validation against modeling. In the Unterinntal, at 38 locations sound levels were recorded for over one week during winter (October to January) and summer (June to August). In addition, the predicted sound pressure levels resulting from PE-modelling have been evaluated against these long-term measurements (van Renterghem et al. 2007).

Indicators of day, evening, night exposure and Lden were calculated for each source. Eventually, total exposure from all or from specific source combinations at several points of the building facade of the participants home was calculated. In the present analyses Lden of the individual sources at the most exposed façade was utilized.

Questionnaire information

The questionnaire covered socio-demographic data, housing, satisfaction with the environment, general noise annoyance due to rail, motorway and main road noise, attitudes toward transportation, interference of activities, coping with noise, work exposures, lifestyles, dispositions such as noise and weather sensitivity, health status, selected types of illnesses and medications. The phone interview took about 15-20 minutes to complete. Due to the longer questionnaire the face to face interview took about 45-60 minutes to complete.

Noise annoyance was measured with a 5-point verbal scale according to ICBEN and ISO standards (Fields et al. 2001; ISO TC 43/SC 1 2002) in the phone study. In the present analyses, highly annoyed was defined by responses to the two upper points (4+5) on the 5-point verbal scale. In the face to face study noise annoyance was measured on a 11-point scale (compliant with ICBEN and ISO standards). The four upper points (8+9+10+11) of the 11-point scale were labeled as highly annoyed. For the pooled sample (N=3,630) scales were standardized to 100 and the cutoff-point for highly annoyed chosen at 72 according to Miedema & Oudshoorn (2001).

Statistical analysis

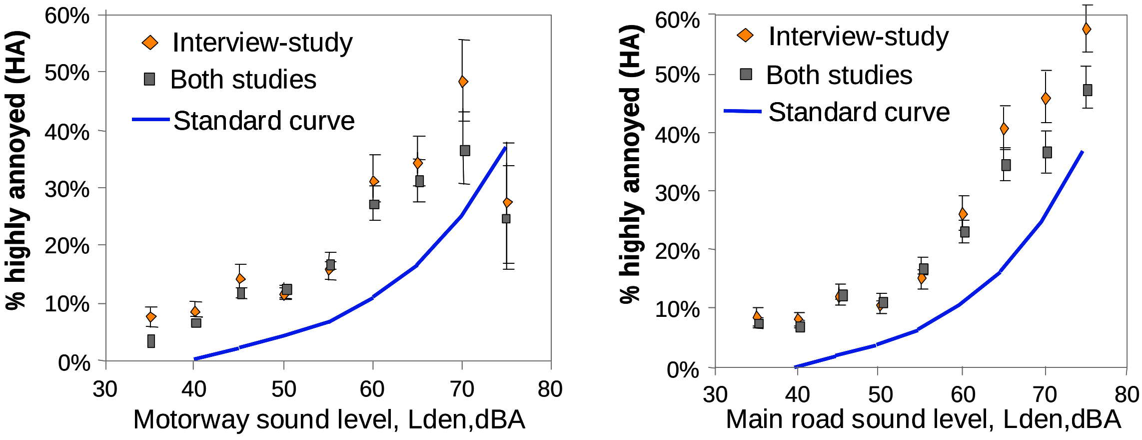
Exposure-effect curves, with the exception of the results shown in Figures 1, 2 and 3, were calculated with extended logistic regression methods using restricted cubic spine functions to accommodate for non-linear components in the fit if appropriate (Harrell 2001). The non-parametric regression estimate and its 95% confidence intervals are based on smoothing the binary responses and taking the logit transformation of the smoothed estimates. The analysis was carried out with R version 2.4.1 (R Development Core Team 2006) using the contributed packages "Design" and "Hmisc" from Harrell.

The results presented in Figures 1, 2 and 3 are obtained by fitting a Gaussian distribution on all levels of annoyance. This technique resembles much more the method used by Miedema & Oudshoorn (2001) and Groothuis-Oudshoorn & Miedema (2006) to obtain what are called the standard curves in this paper. In contrast to them we did not assume the relationship between annoyance level and noise level would be linear but considered several 5 dBA classes.

RESULTS

Figures 1, 2 and 3 show a side-by-side comparison of the noise-annoyance relationships for motorway, main road and railway sound levels noise modeling of the BBT-studies. For comparsion, the standard exposure-annoyance curve (from END) is inserted.

The strongest deviation from the standard curve is observed in the railway graph at levels above 70 dBA while below 50 dBA a reasonable agreement is visible. Conversely, in both road traffic curves a stronger deviation is observed already at low levels and again between 60 and 70 dBA - but much less when compared with motorway sound modeling. The interview sample displays slightly higher annoyance.



Figures 1 and 2: Exposure effect relationships: highly annoyed by motorway (left) and main road sound exposure (right) by different noise modeling procedures compared with the standard curve (Environmental Noise Directive). Vertical lines indicate 95 % confidence intervals.

In Figure 4 area differences between the northern and southern Wipptal are revealed. While rail exposure is more dominant in the South, in the North road noise triggers stronger annoyance. It is also visible that the rail-bonus is lost above 60 dBA, where the slope for rail noise is leveling off quite strongly.

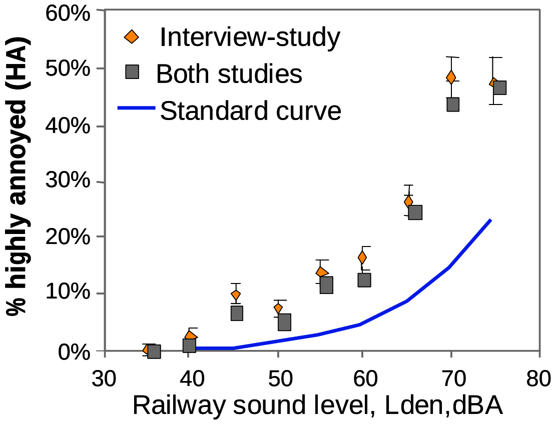


Figure 3: Exposure effect relationship: highly annoyed by railway sound exposure modeling compared with the Standard curve

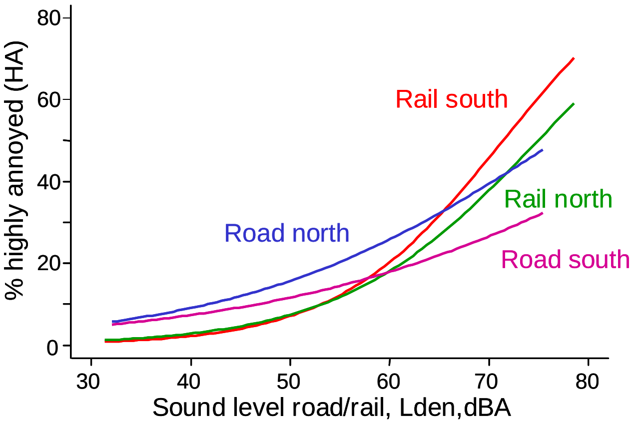


Figure 4: Exposure effect relationship: highly annoyed due to railway and road exposure by subarea: North versus South (phone study)

Figures 5 and 6 display the effect relationships in the Inntal (ALPNAP). The main road effect relationship is quite striking. All curves depart significantly from the standard. We see a clear rail bonus with the Lden indicator – but not when Lnight (Figure 6) is used. During night, the motorway remains the most annoying source below 50 dBA.

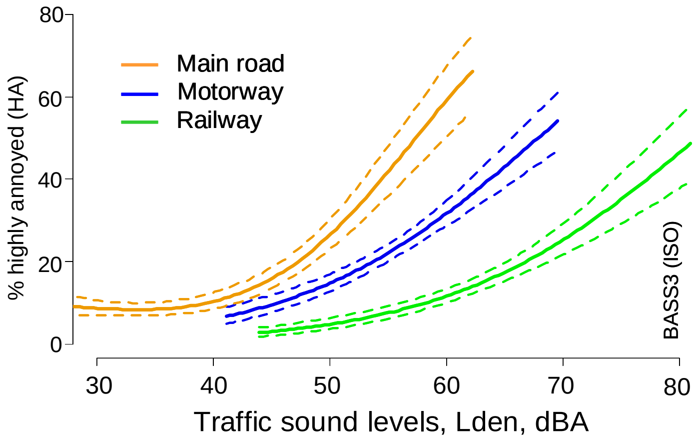


Figure 5: Exposure effect relationships: highly annoyed by motorway, main road and rail. **Lden** (ALPNAP: Unterinntal)

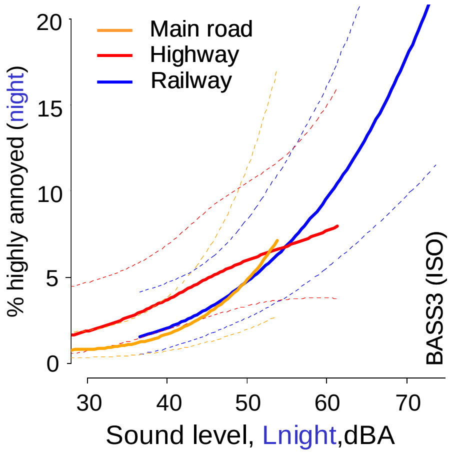


Figure 6: Exposure effect relationships: highly annoyed **during night** by motorway, main **Lnight** (ALPNAP: Unterinntal)

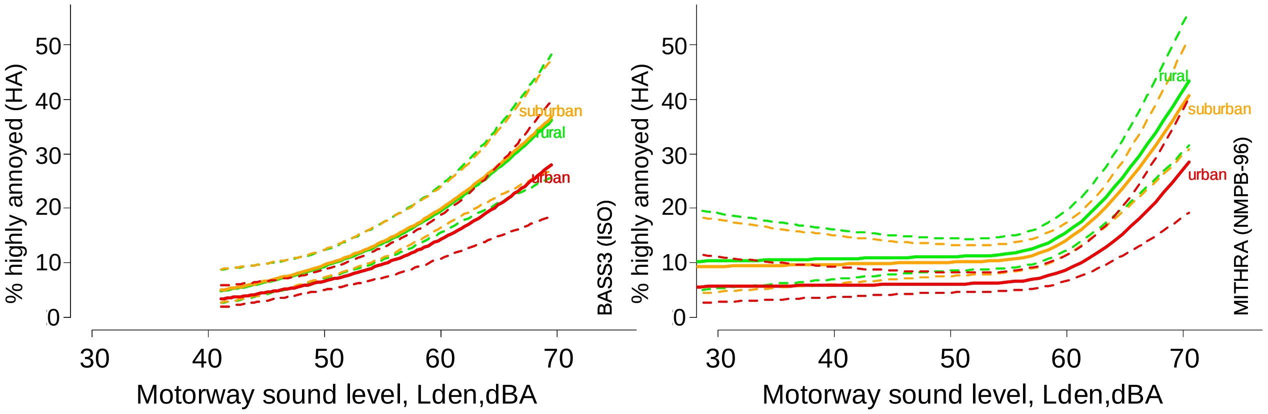


Figure 7: Exposure effect relationships by residential layout (urban-suburban-rural: highly annoyed by motorway noise by two different noise modeling procedures (left: Bass3-ISO right: Mithra- NMPB-96)

Figure 7 shows a significant difference between the effect relationship for motorway noise depending in what residential layout people live in (left graph). The relationship is repeated also with a different noise mapping procedure (right graph). It is also visible from the comparison that the different mapping procedures lead to a quite different effect relationship: the ISO-curve showing stronger departure from the standard curve. While there is a continuous increase in annoyance seen with the ISO mapping we observe only later a steeper slope starting around 60 dBA in the MITHRA mapping. In spite of this difference the effect of the residential layout remains about the same.

DISCUSSION

The three cross-sectional studies conducted in two different alpine valleys along a major transalpine traffic route have revealed quite different exposure effect curves for railway, motorway and main road traffic noise exposurer. The most significant overall departures seen can be summarized as follows:

- All curves show substantial departure from the standard curves
- A rail bonus is not seen in the Wipptal studies above 60 dBA but below these exposure levels
- Although a rail bonus is observed in the Inntal studies with the overall noise indicator Lden – this is not repeated when Lnight is used as noise exposure indicator
- The interview sample (highest participation: 80 %) displayed slightly higher percentages of highly annoyed at higher exposure levels
- The Wipptal studies have shown quite striking difference with respect to annoyance of the different sources at the same exposure levels
- Residential layout (urban versus suburban and rural) can be a significant factor in displayed annoyance
- Different mapping procedures may lead to a quite different effect relationship.

Before interpreting these special findings some additional information must be provided here to allow a well-informed discussion.

- Since 25 years there has been a continuous increase in both passenger and heavy goods traffic.

- Within this timeframe a slight shift of heavy goods traffic from road to rail has occurred. The shift has resulted in higher night exposure since the additional heavy goods trains had to be rescheduled from day to night.
- Since December 1989 a night ban was implemented for trucks not fulfilling the label “low noise”. This has decreased significantly noise exposure during night from trucks on the highway (about 3 dBA reduction in level).
- In both valleys several noise abatement strategies have been implemented (noise barriers nearly along the whole route on both, the motor- and railway).

Although there has been signs of a normalization of the railway annoyance curve in the Inntal – the curve in the Wipptal did not show the same development. The smaller distance to the slopes in this V-valley compared with the Inntal (U-valley) is a possible explanation. The direct propagation of noise to the slopes (no ground effect) may still be underestimated in the noise mapping (van Renterghem et al. 2007).

Consequently, the efficiency of noise barriers is largely compromised.

Since the rail bonus is still lost in the Inntal during night this may be related to the larger signal to background ratio which displays during night in the alpine valleys and increases the detectability and therefore the perception of sound in a human state of enhanced susceptibility (see notice event concept in Botteldooren et al. (2008) at this conference).

A further explanation was put forward in two other papers where the effect of noise exposure from mixed sources is explored (Lercher et al. 2007; Botteldooren et al. 2007). In these analyses we have found that the rail noise annoyance curve in the Inntal is not displaying a more shallow slope beyond 300 m of the rail track as has been observed in a large survey in a flat area (Flandern, Belgium).

Eventually, not every applied noise mapping procedure may be appropriate for use in both alpine valleys and flat areas. This is evidenced by the comparsion in Figure 7 and in an accompaying paper (Lercher et al. 2008 at this conference).

CONCLUSION

Although enormeous efforts have been made to cope with the increasing rail and road traffic over the Brenner pass in the Tyrol by implementing noise abatement measures along both tracks noise annoyance curves still display strong departures from the standard curve of the END. The lower background level experienced in alpine valleys, the direct propagation of the noise to the slopes and possible effects from the combined exposure of rail and road traffic are likely to contribute to the consistent deviation from standard curves. Finally, not all noise propagation routines may be able to provide adequate noise mapping in alpine areas.

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