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Summary:

People's reaction to vibrations in dwellings from road and rail

In connection with the development of a new Norwegian Standard for measuring vibrations in buildings from road and rail traffic, an environmental survey was undertaken in 1997/8. Its purpose was to establish exposure-effect relationships using the vibration velocity measure specified in the standard. This measure is the statistical maximum value of the weighted vibration velocity $v_{w,95}$.

Telephone interviews in 12 study areas of 1161 respondents between 18 and 75 years were undertaken in September 1997, and supplemented in September 1998 with an additional 342 respondents from two areas with high vibration values. The telephone interviews were conducted by a professional marketing organisation. Non-response was 50%, which is high, but as expected in this type of survey.

For 1427 of the 1503 addresses, it was possible to determine the geographical coordinates of the dwellings and calculate a vibration value. The vibration values were calculated on the basis of ground surface measurements and by measurements inside buildings by the Norwegian Geotechnical Institute. The vibration values were calculated using a semi-empirical prediction model for vibration propagation. The prediction model is based on a comprehensive analysis of a number of vibration measurements and the connected ground and construction data. Many people are annoyed at low vibration values

People react differently to vibrations. Vibrations that cause some people annoyance do not bother others. At the same time there is a clear and systematic relationship between the percentage of people experiencing different effects and the vibration velocity. This relationship can be determined by a statistical analysis of people's responses and be illustrated as an exposure-effect relationship. The relationship between the degree of annoyance and the logarithm of the vibration measure –$\log_{10}(v_{w,95})$ – has been estimated by an ordinal logit model. The exposure-effect curves for the relationship between $v_{w,95}$ and the probabilities for experiencing different degrees of annoyance have been illustrated in figure S.1 .

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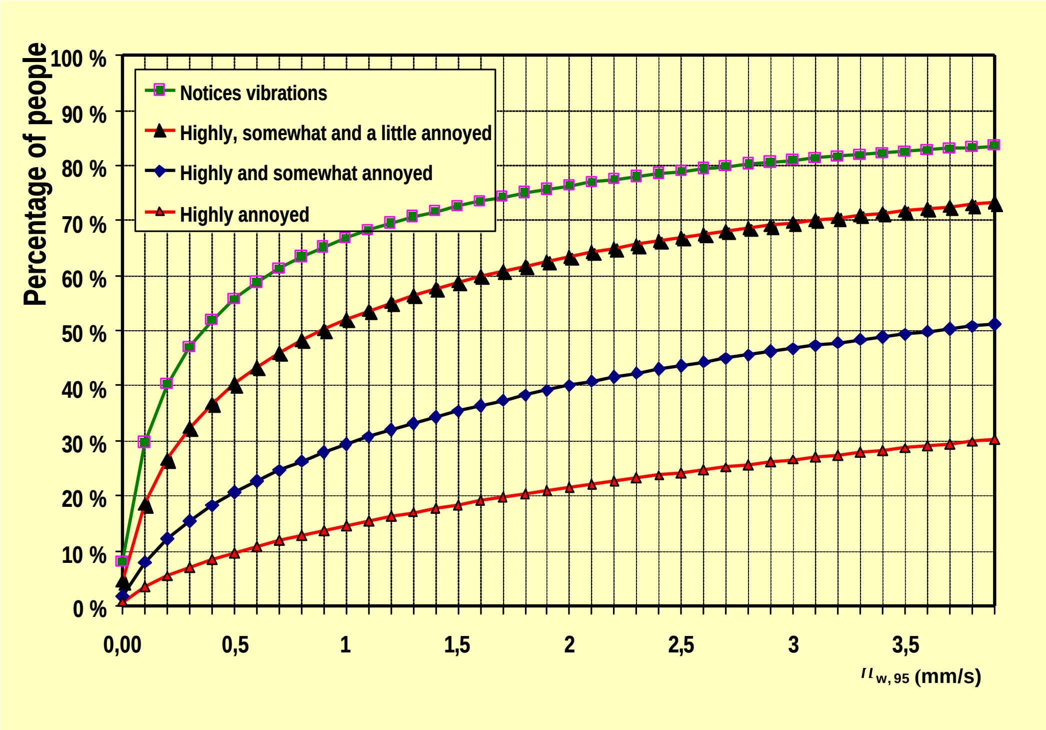

Figure S.1: People reporting different degrees of annoyance by the strength of the vibrations $v_{w,95}$. *Linear scale. Norwegian Vibration Survey 1998. N=1427. Percentages.*

From the relationships it can be seen that approximately 10% of the persons are highly annoyed ("meget plaget") while about 40% are annoyed (highly, somewhat, a little) at a vibration value $v_{w,95}$ of 0,5 mm/s.

Road and rail exposure-effect relationships the same

Vibrations from road and rail have different frequency distributions. As people react differently to vibrations with different frequencies, the frequency spectrum is weighted in order to account for such differences. The fact that there were no significant differences in people's reactions to vibrations from different sources, suggests that the frequency weighing has been successful and that exposure-effect relationships can be estimated without consideration of the actual vibration source.

The linear scale utilised in figure S.1 provides a direct relationship between vibration values and the percentage of the population experiencing different degrees of annoyance. It can be made more user friendly by displaying the vibration values on a logarithmic scale. The same curve is thus illustrated with the vibration values following a logarithmic scale – see figure S.2.

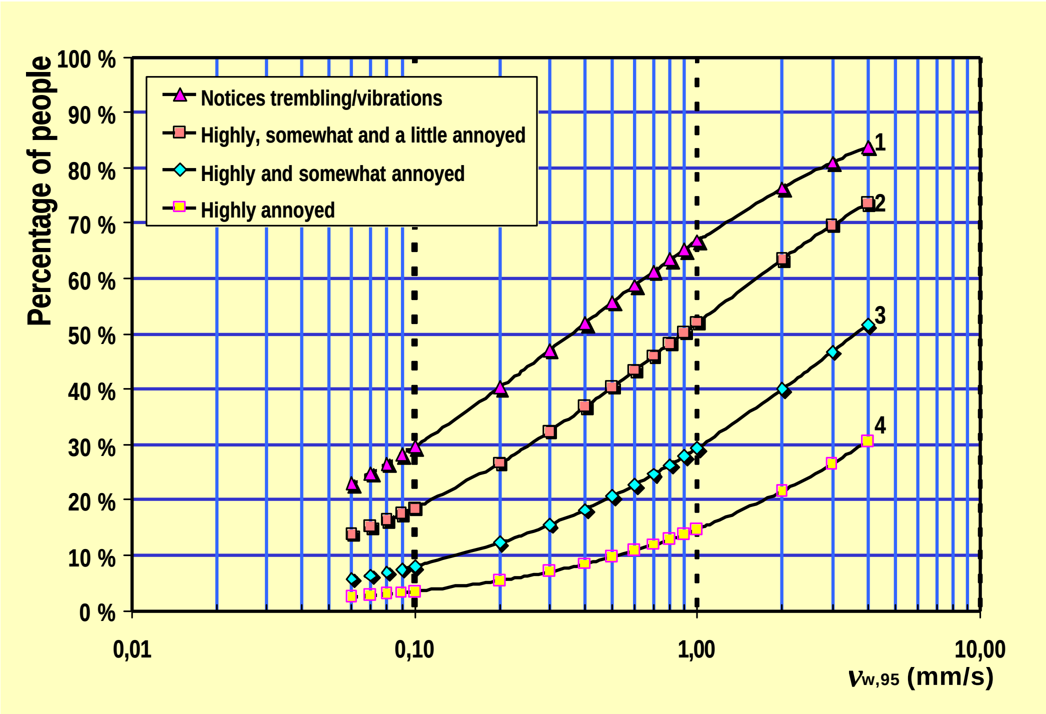

Figure S.2: People reporting different degrees of annoyance by the strength of the vibrations $v_{w,95}$. *Logarithmic scale. Norwegian Vibration Survey 1998. N=1427. Percentages.*

In this project the vibration measure specified in the standard, has been used as the exposure measure without taking into account the number of events or their duration. Combined effects have not been considered other than through the selection of study areas where the indoor 24 hour-equivalent continuous sound pressure level should be below 30 dB. However, the estimated relationship for people highly annoyed by log($v_{w,95}$) with control for the effect of age-group pass the goodness of fit test specified by Hosmer and Lemeshow (1989) with good margin (p=0.70).

As the study areas where chosen so as to include railroad stretches and roads carrying quite high levels of traffic, there is a chance that people's reactions will be lower when traffic volume is much less. The exposure measure might be improved by building a composite exposure measure explicitly taking into account the number of events and duration.

Exposure-effect relationships for disturbances

At a vibration value of 0.3 mm/s about 20% of the respondents report that *the building shakes/trembles often*, while 9% report that furniture and household items *often scramble* and that they *often feel the vibrations bodily see figure S.3*. The people that are *highly annoyed* are those who most often notice the vibrations these ways.

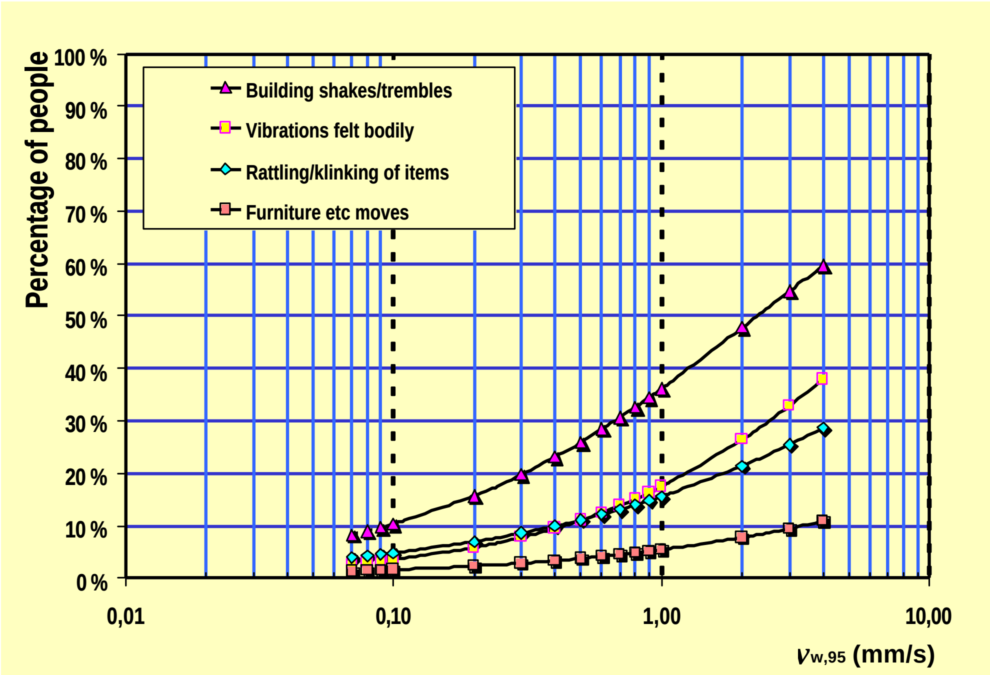

Figure S.3: People reporting how often they notice vibrations in different ways, by the strength of the vibrations $v_{w,95}$. *Logarithmic scale. Norwegian Vibration Survey 1998. N=1427. Percentages.*

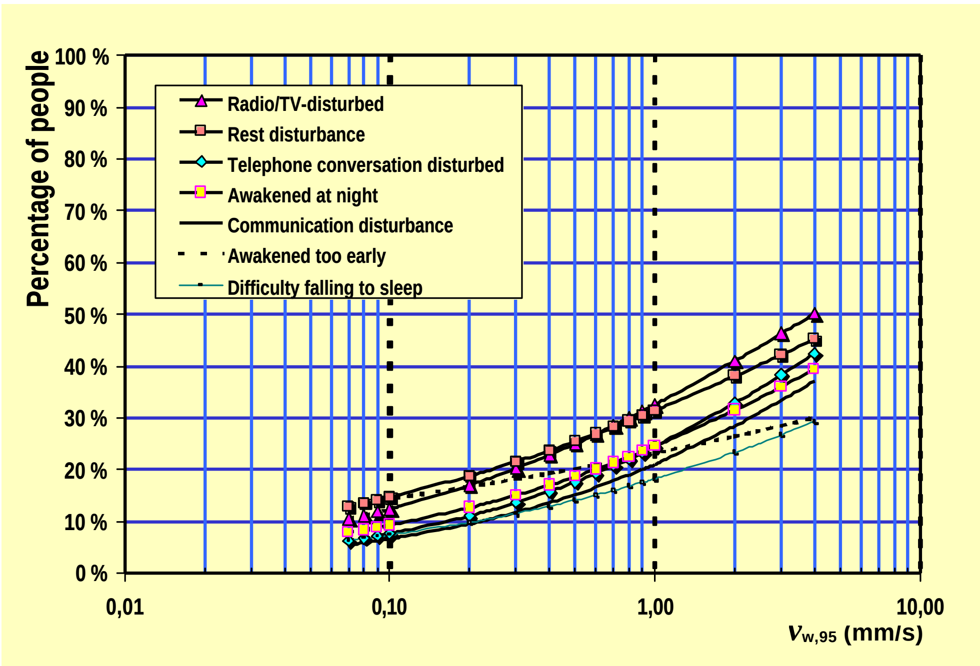

Figure S.4: People reporting different activity disturbances, by the strength of the vibrations $v_{w,95}$. *Logarithmic scale. Norwegian Vibration Survey 1998. N=1427. Percentages.*

Listening to the radio or watching TV are the activities that most people report are disturbed by vibrations from road and rail traffic– see figure S4. Between 10 % and 15 % of the respondents report resting and sleep disturbances at a vibration value $v_{w,95}$ of about 0,1 mm/s.

Vibration classification of buildings

The exposure effect relationships described above provide Norwegian data that can be used for classifying dwellings with respect to vibrations. The standard specifies 4 vibration classes, A, B, C and D with limits. Class C is of special importance as the attainment of this quality level is recommended to be used when planning new buildings and new road and railroad lines. Class D is intended to be used for existing dwellings when Class C is not attainable because of cost-benefit analyses

The different building classes are guidelines. The boundary values were chosen so as to result in the same annoyance and disturbance levels as do road traffic at its corresponding boundary values. This type of reasoning suggests that vibration values $v_{w,95}$ around 0.25 to 0.3 mm/s should be used as upper limit for class C. Vibration values $v_{w,95}$ around 0.5 to 0.6 should be used for Class D. These values are lower than the ones previously proposed.

Quality of the exposure-effect relationship

The quality of the results is mainly dependent on the chosen exposure measure and the lack of control of the associated noise levels. The statistical errors caused by the estimation process are small due to the efficiency of the ordinal logit model – see figure S.5.

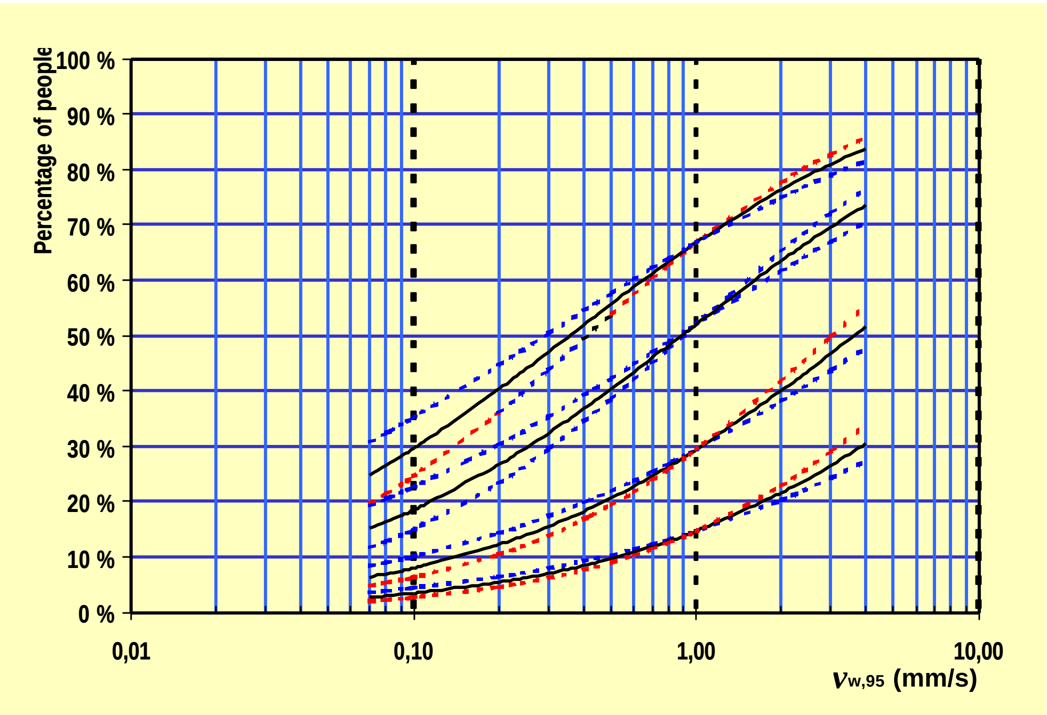

Figure S.5: Variation in the estimated probabilities when the parameter for the vibration measure varies within a 95% confidence interval. Probabilities estimated by means of a ordinal logit model. Norwegian Vibration Survey 1998. N=1427.

The survey is a community survey designed to capture responses from people who are highly annoyed or disturbed. It is not an experimental study designed to define perceptual thresholds etc. We have therefore chosen to use dashed lines for vibration values below 0,1 mm/s in figures S.2 to S.4 to indicate that other factors than vibrations have a relatively stronger impact on reactions at such low vibration values.