MADRID
inter.noise 2019
June 16 - 19
NOISE CONTROL FOR A BETTER ENVIRONMENT

A Survey of Noise Disturbance in Swedish Farms of Large Wind Turbines

Pendrill, Leslie[1]
RISE Research Institutes of Sweden
Eklandagatan 86, SE41261 Gothenburg, Sweden

Glebe, Dag[2]
RISE Research Institutes of Sweden
P.O.Box 857, SE50115 Borås, Sweden

ABSTRACT

In 2015, a project was initiated to investigate what factors were dominating the perception of wind turbine noise in the vicinities of seven wind farms in Sweden with relatively large wind turbines. The project included, besides two listening tests, a survey of perceptual and socioeconomic factors. In a questionnaire to habitants in the vicinity of the investigated wind farms, questions were asked regarding their housing situation, living conditions, the bedroom's orientation towards wind turbines, noise disturbance, visual impact from wind turbines, economic incentive models, ownership structures, general attitudes about wind power, and more. The purpose was to provide a holistic basis for a future synthesis model for disturbance, and this project focused on the correlation between noise disturbance and visual impact from wind turbines, ownership structures and financial compensation models from the wind farm. The questionnaire was analysed with psychometric methods, including logistic regression and multivariate techniques as principal component regression. The results of the psychometric analyses showed a large spread in sensitivity to disturbances (both visual and acoustic) from wind power plants, but the most difficult elements could be identified for various factors in the questions, including e.g. audial and health factors, and the quality of financial compensation.

Keywords: Wind Turbine Noise, Environment, Disturbance, Questionnaire, Rasch
I-INCE Classification of Subject Number: 56

1. INTRODUCTION

1.1 Background

It is a well-known fact that community noise is an increasing environmental problem which is known to cause adverse health effects (e.g. [1]). In comparison with other sources of sound such as traffic noise, wind turbines give rise to a higher degree of disturbance given the noise level (e.g. [2]). Several studies have been funded by the Swedish EPA (Environmental Protection Agency, in Swedish Naturvårdsverket) in order

[1] leslie.pendrill@ri.se
[2] dag.glebe@ri.se

to account for Swedish conditions [3]. It has been shown that there is a dose–response relationship between A-weighted SPL and the frequency of disturbance [4], and this forms a base for noise regulations. Therefore, in the recommendations from the Swedish EPA and the Swedish National Board of Housing, Building and Planning (Boverket) it is primarily stated that the sound level from wind turbines in Sweden should not exceed 40 dBA in residential zones (or 35 dBA if low sound levels are desired). In addition, general practices for environmental noise are recommended. E.g., if the difference between A-weighted and C-weighted sound levels exceeds 20 dB, the Swedish EPA recommends that the low frequency noise is assessed and the guidelines for indoor low-frequency noise are considered. If the sound contains clearly audible tones, the value should be 5 dBA lower (corresponding to the general guidelines for indoor noise in e.g. [5]). However, no models or penalty schemes for amplitude modulated sound are given in the Swedish recommendations (cf suggestions in UK [6][7]). And so, there is a great interest in studying how well the existing recommendations match the opinions of residents living in the vicinity of wind farms.

In the last few years, there has come a new generation of wind turbines with an apparent increase of performance and a corresponding increase of height and size. The project aimed to establish whether there was a risk that the large wind turbines (> 90 m rotor diameter) would lead to a higher degree of disturbance among people living in their vicinity. The assignment included both a questionnaire and a listening and mapping of the noise levels in affected areas.

1.2 Project Overview

The presented project was organised in three WPs and involved seven wind farms in Sweden with large wind turbines. In WP1 measurements were performed based on applicable parts of the IEC6140-11/ISO1996 standards and recordings at the wind farms. In WP2 the recordings were used as a basis for designing test files for a paired comparison listening tests of perceived disturbance, and for a semantic differential test. WP3 contained a questionnaire study on the perception of the wind turbine noise and the socio-economic situation was designed and analysed. This paper will focus on and discuss the results and analyses of the questionnaire study in WP3.

2. METHOD

2.1 Selection

The questionnaire was sent out to residents around the seven wind farms that were studied in this project. All homes within five kilometres from the wind farms were selected, which included 2905 people. Of these persons, one respondent was randomly chosen per household, which resulted in 1462 participants in the survey. The questionnaire was then mailed to the participants, which meant one to three mailings; the first two mailings also contained login information to internet for questionnaire responses, the last mailing contained a paper copy of the questionnaire and a pre-paid return envelope. When a participant responded, this was registered anonymously, and only those participants who did not respond received reminders. A total of 624 participants chose to answer the questionnaire (42.7%).

Table 1: Demographic data and background variables. Number of respondents per question and category. Percentage of respondents to the question in parentheses.

Sex	Female	Male
(n=595[a])	260 (43.6%)	336 (56.4%)

Age ()	18 - 35 years	36 – 50 years	51 - 65 years	66 - 80 years	81+ years
(n=582[a])	31 (5.3%)	116 (19.9%)	203 (34.9 %)	203 (34.9 %)	35 (6.0 %)

Education level	Lower Secondary	Upper Secondary	Tertiary 0-3 years	Tertiary >3 years
(n=573[a])	117 (19.3%)	164 (27.0 %)	133 (21.9 %)	159 (26.2%)

Residential type	Permanent	Seasonal
(n=554[a])	528 (89.5%)	62 (10.5%)

Period of residence (years)	0 – 5 years	6 – 15 years	16 - 30 years	31 - 50 years	51 + years
(n=554[a])	73 (13.2%)	124 (22.4%)	162 (29.2%)	148 (26.7%)	47 (8.5%)

Number of residents	1 adult	2+ adults	1 adult 1+ children	2+ adults 1+ children
(n=577[a])	107 (18.5%)	272 (47.1%)	28 (4.9%)	170 (29.5%)

2.2. Questionnaire

The questionnaire was used in two different projects and designed by members from both the project teams. The questions addressed various conditions of the participants: housing situation, living conditions, the orientation of the bedroom with respect to the wind turbines, noise pollution, visual impact from the wind turbines, other perceived impact from the wind turbines, general attitudes about wind power, financial compensations from the wind farm, demography, health, sensitivity for sounds and negative emotions/affectivity. The majority of the questions have previously been used in research on wind power noise and were selected because in previous studies they have been shown to address factors that were relevant for the perceived disturbance.

2.3. Data Processing - Descriptive Data

The processing and production of the descriptive data was first performed by the other project and is not presented in detail here. The disturbance from the noise sources was evaluated with an ISO standard question [8].

2.4. Data Processing - Psychometric Evaluation

The questionnaire was analysed with psychometric methods, including logistic regression and multivariate techniques as principal component regression. Survey questions about

(i) wind power and disturbance were analysed in terms of each individual's sensitivity, θ, to disturbance and the degree of difficulty, δ, of the disturbance;

(ii) questions addressing demographics, health and attitudes were analysed in terms of each individual's degree of health, θ, and the severity, δ, of every aspect of health;

(iii) questions about financial compensation from the wind farm were analysed in terms of each individual's degree, θ, of leniency and each compensation model’s degree of quality, δ.

In order to fully benefit from the information in the questionnaire response, separate estimates were made of person and object attributes. In order to properly manage the ordinal data of the questionnaire responses, a psychometric logistic regression was applied, where the logarithmic odds for a successful response (the response probability) were modelled as linearly varying with the difference between a respondent attribute, θ ("ability") and a task's severity, δ ("challenge level") [9] [10]:

$$log\left(\frac{P_{success}}{1-P_{success}}\right) = \theta - \delta \qquad (1)$$

Attribute values were obtained by transforming data, with Equation 1, from being "raw" ordinal points to being instead on a quantitative range scale, where all common statistical and metrological tools can be applied (as opposed to ordinal scales [11]). The approach makes it possible to reveal the non-linearities that are characteristic of ordinal data [12], Figure 5. A systematic examination of Equation 1 can be made either for a fixed personal attribute value, θ, and for a number of object attributes δ, or *vice versa*.

A major advantage of this Rasch method of invariant measures is that it provides:

- A measure of severity of each question that is not affected by the ability (or attitudes) of individual respondents.
- Measurements of the ability (or attitudes) of each respondent that is not affected by the difficulty of single question [13]
- I.e. if one compares the difficulty levels of different questions, one can predict which one can be expected to give higher values on the response scale. If you know how high the "ability" is for the respondent and how high the "degree of difficulty" is on the question, then you can estimate what answers you can expect on this particular question.

The following nomenclature is used:

$$i = \begin{cases} 1, respondent\ A \\ 2, respondent\ B \\ 3, respondent\ C, \ldots \end{cases} \quad j = \begin{cases} 1, disturbance\ a \\ 2, disturbance\ b \\ 3, disturbance\ c, \ldots \end{cases} \quad c = \begin{cases} 1, question\ Q1 \\ 2, question\ Q2 \\ 3, question\ Q3, \ldots \end{cases}$$

In cases where the questionnaire responses are divided into more than 2 (k = 1, …, K)) categories, the polytomous Rasch model [14] [15] is used, which gives the response probability $v_{i,j}$ for the respondent i to disturbance j:

$$P\left(v_{i,j} = c\right) = \frac{e^{\left[c\cdot\left(\theta_i-\delta_j\right)-\sum_{k=1}^{c}\tau_{k,j}\right]}}{\sum_{c=0}^{K_j} e^{\left[c\cdot\left(\theta_i-\delta_j\right)-\sum_{k=1}^{c}\tau_{k,j}\right]}} \qquad (2)$$

where τ_k represents the threshold for category k.

3. RESULTS

3.1 Disturbance - Descriptive Data

To assess how prominent wind turbines are as a source of disturbance in comparison to other types of noise sources, all sources were compared with respect to how many respondents found them disturbing. Figure 1 shows that wind turbines are the most common source of disturbance among the participants: 1.75 times more participants experience the sounds from the wind turbines disturbing (7.2%) compared to road traffic noise (4.1 %).

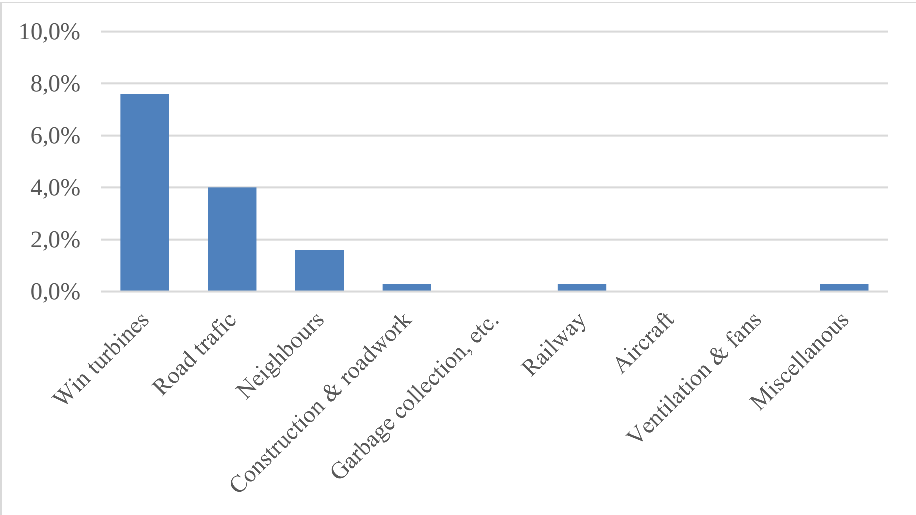

Figure 1 Percentage participants disturbed by the nine sound source categories in the questionnaire. The x-axis shows the sound sources, and the y-axis the number of participants in percent who considered themselves disturbed of the corresponding noise.

The proportion of respondents who stated they were disturbed by wind power was also compared between the seven wind farms in the study and is reported anonymously. The proportion of respondents disturbed by wind turbines was stratified: The two wind farms where most participants reported being disturbed the proportions were 13.4% and 13.3% respectively. At a clearly lower level, there were two parks with 5.3% and 5.2% respectively. Just below that, there were two parks with 3.9% and 3.3% respectively. In one of the parks, no participants reported being disturbed, Figure 2.

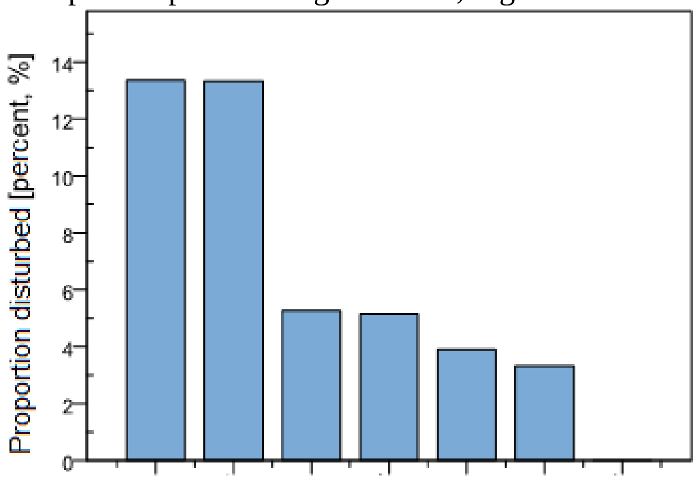

Figure 2 Percentage of respondents who reported that they were disturbed by wind power noise around the six wind farms. The wind farms are along the x-axis, while the y-axis shows percentage of participants being disturbed by noise

3.2. Disturbance - Psychometric Analysis

The answers to 10 questions addressing wind power and disturbance were analysed in terms of each individual's sensitivity, θ, to disturbance and the degree of difficulty, δ, of the disturbance; In this context, the interpretation of the nomenclature is:

- A higher sensitivity, θ, to disturbance increases an individual's tendency to assess the disturbance as high, in their responses.

- A higher degree of difficulty, δ, of a question means that the question (aspect) itself will generate responses with a higher assessed disturbance.

The results of the psychometric analyses indicated a large spread in sensitivity to disturbances from wind turbines (both visual and acoustic) among the 500 individuals who responded to the survey. The most disturbing element was linked to the question "How do you generally perceive the noise level from the wind power plants closest to your home?" The least disturbing was that it was difficult to have windows open during the day, Figure 3.

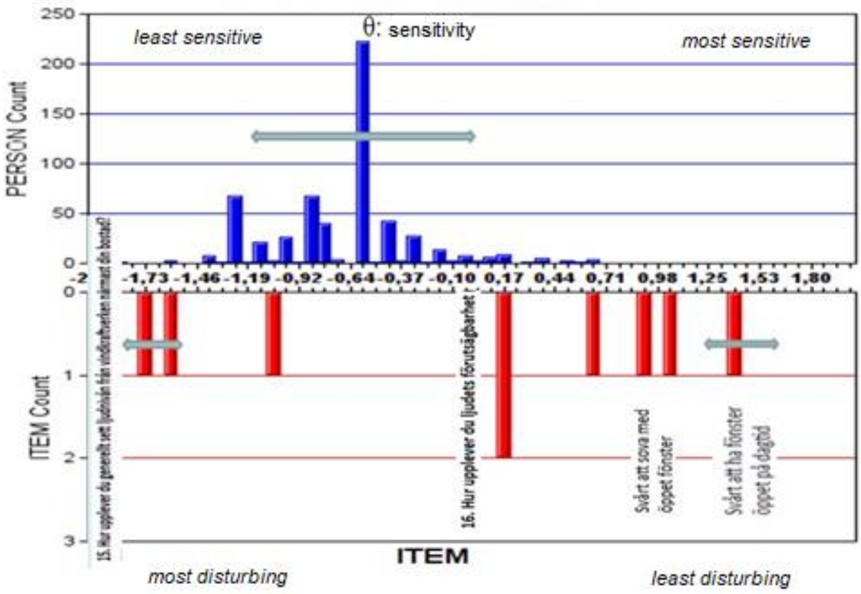

Figure 3 Psychometric histograms of respondent sensitivity [blue bars] to aspects of wind turbine noise disturbance [red bars in Swedish, cf. comments in text] among the 500 participants (Rasch analysis with Eq. 2 applied on answers about disturbing noise). The double-ended horizontal arrows indicate extended measurement uncertainties [k = 2].

There were signs of a weak positive correlation between each individual's sensitivity to disturbance and their age. There was no correlation at all between the individuals' sensitivity to disturbance with either annual income or general health, however, Figure 4.

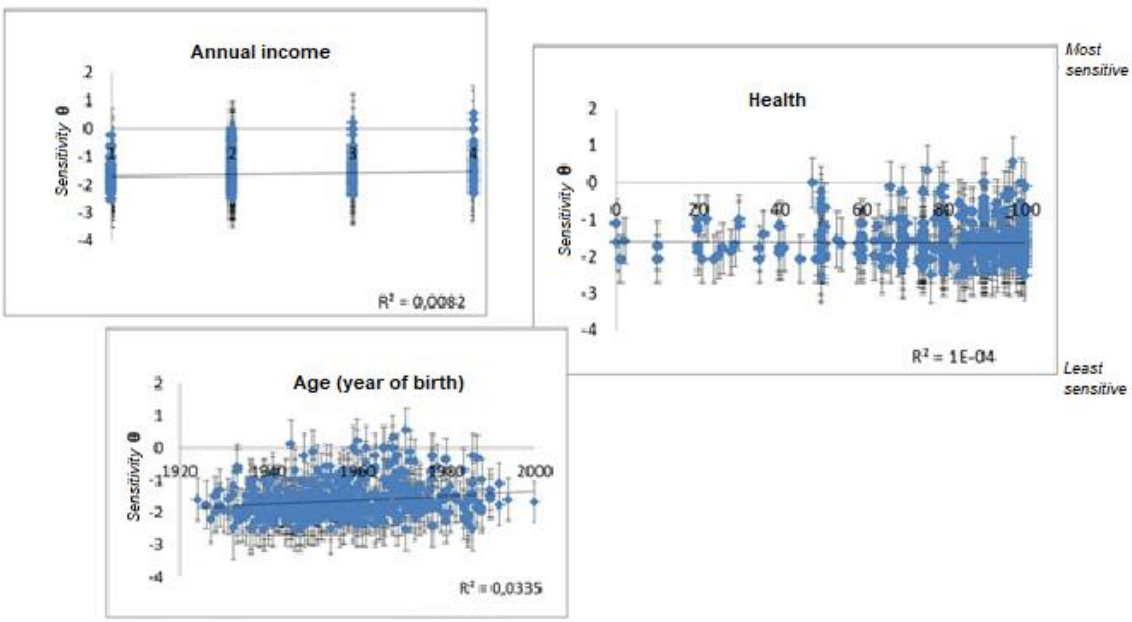

Figure 4 Correlation diagram of each individual's sensitivity, θ, to disturbance, plotted against their age, annual income and general health [extended measurement uncertainties k = 2]

There was a weak positive correlation between each individual's sensitivity, θ, to disturbance (including both visual and audial disturbance) and the calculated local sound level (L_{pA}), Figure 5.

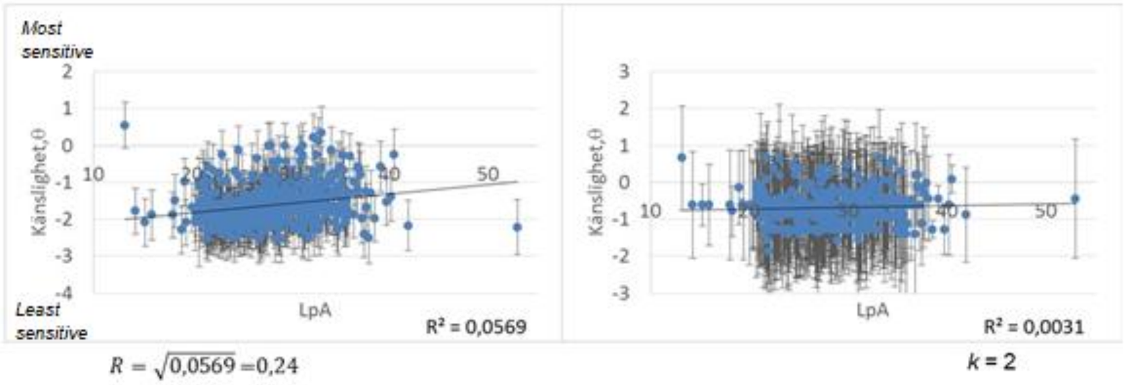

Figure 5 Correlation diagram of each individual's sensitivity, θ, to disturbance with the corresponding calculated local sound level (LpA). Left figure: general disturbance (including both visual and audial disturbance), and right figure: only noise disturbance. [extended measurement uncertainties k *= 2]*

3.3. Demography, Health and Attitudes - Psychometric Evaluation

In the psychometric analysis of the questions on demography, health and attitudes, it was found that the highest degree of difficulty was found in the question “Do you have tinnitus?” This means that those who answered that they had tinnitus could generally be expected to assess the disturbance level highest. The lowest level of difficulty had the question “Are you depressed?”. Those who responded that they were depressed were generally inclined to assess disturbance level lowest, Figure 6.

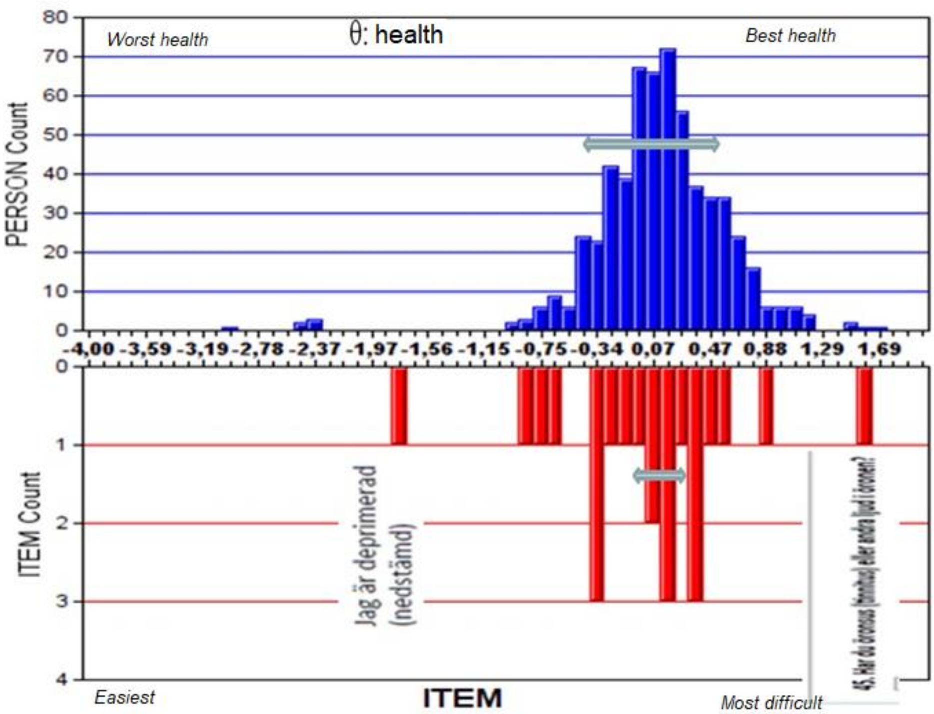

*Figure 6 Psychometric histograms of health ability, θ [blue bars], of respondents and degree of difficulty, δ, of each health aspect [red bars] among respondents (Rasch analysis with Eq. 2 applied on answers to questions on demography, health and attitudes). The double-ended arrows indicate extended measurement uncertainties [*k *= 2]*

The correlation, however, was non-existent between each individual's sensitivity, θ, to disturbance and their hearing ability, Figure 7.

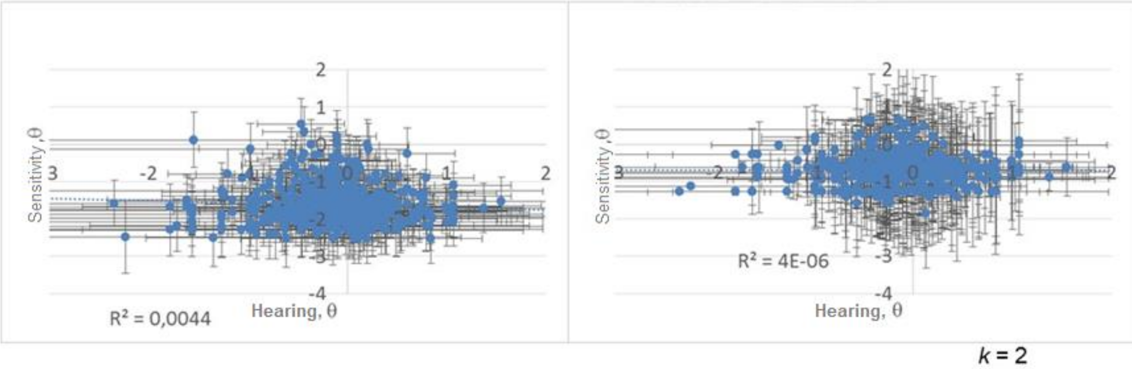

Figure 7 Correlation diagram between each individual's sensitivity, θ, to disturbance and their hearing ability [extended measurement uncertainties k = 2]

3.4. Financial Compensation from Wind Farms

For the individual perception of wind turbines, one factor that has been shown to affect the degree of disturbance is financial incentives. Bakker [16] showed that of those who did not receive any financial gain from the wind turbines, approximately 7 per cent of the residents were rather or very disturbed by the indoor wind turbine noise, whereas the corresponding figure for the residents with some form of financial gain was instead 0 per cent. These and other socio-economic factors, such as the possibility of shared ownership of the wind turbines, were planned to be analysed with regard to how they affected perceived disturbance. Only a small portion of the participants were affected by economic incentive models (70 people), and the data were much smaller when they were divided into rather disparate incentive models. The data sets were so small that only the psychometric methods yielded results in the analysis.

The visual impact was also examined in the survey. However, the correlation to disturbance was low in the related questions (between 0.28 and 0.35)

3.5. Psychometric Analysis of Questions Regarding Financial Compensation

Questions about financial compensation models from the wind farm were analysed psychometrically in terms of each individual's degree, θ, of leniency (how inclined the individual was to be satisfied with a compensation model) and the degree, δ, of quality of each form of compensation (how good the model fulfilled its purpose to increase the individual's satisfaction with the model). The interpretation in this case was:

- A higher degree, θ, of leniency, increases an individual's inclination to assess his/her satisfaction with any compensation model as high in his/her response.
- A higher degree of quality, δ, of a compensation model increases the respondents' inclination in their responses to assess their satisfaction with this model highly

As a result of the PCR analysis, a formula could be derived for predicting an individual's sensitivity to disturbance from wind turbine noise, despite the limited response data:

$$\theta_i = -0{,}4(3) - 0{,}002(2) \cdot Age_i[a] - 0{,}03(5) \cdot Educ_i[a] - 0{,}001(2) \cdot Health_i[logit] + 0{,}01(4) \cdot Income_i[cat. 1-4],$$

where the numbers in parentheses indicate extended measurement uncertainties with coverage factor k = 2.

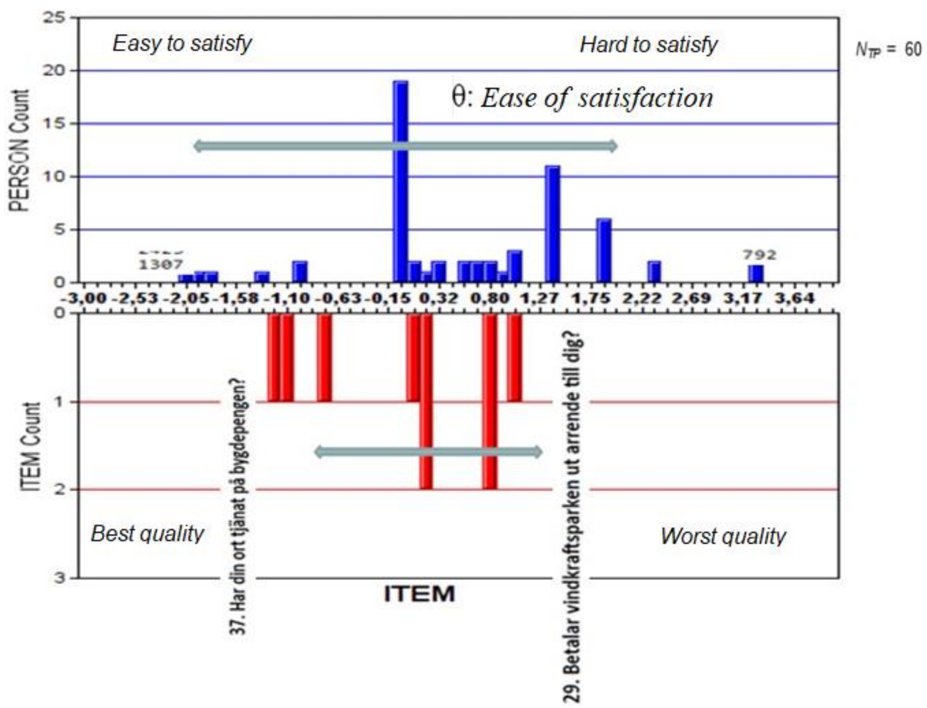

*Figure 8 Psychometric histograms of degree of leniency, θ, of respondents [blue bars] to quality, δ, of each financial compensation model [red bars]) among respondents [Rasch analysis with Eq. 2 applied on answers to questions about financial compensation]. The double-ended horizontal arrows indicate extended measurement uncertainties [*k = 2*]

Despite the low response rates for financial compensation issues from the wind farm, each individual's degree, *θ*, of leniency and each compensation model's degree of quality, δ, could be analysed. As a result, it was found that the compensation model that was perceived to have the highest quality was addressed in the question “Has your community benefited from a compensation scheme?” The worst quality assessment was generated by the question “Does the wind farm pay rent to you?” There was no correlation at all between the individuals' leniency with the compensation model and their annual income, or their sensitivity to disturbance from wind turbines noise.

3.6. Reliability and Validity

Since limited measurement quality can lead to increased risks for incorrect decisions (e.g. acceptance of a substandard compensation model, section 3.7), it is important to correctly evaluate the measurement uncertainty.

Measurement reliability [17] is a measure of whether each outcome gives the same number each time a measuring instrument is applied. With people as "measuring instruments", it is necessary to make a distinction between repeated measurements with one person as opposed to measurements with different people. Three (of several) aspects of reliability are in focus here; self-reporting, internal consistency and respondent ability (reproducibility):

1. Self-reporting: Reliability estimated from words and interpretation

The psychometric Rasch analysis has not revealed any significant differences related to the interpretation of the survey questions regarding the scoring of the respondents.

The reliability of estimates of individual respondent attribute values (such as sensitivity or ease of leniency) was typically limited, taken over all issues and challenges, especially at the extreme ends of the measurement scales. As shown in Figure 9, there is a certain lack of matching of high sensitivity to low difficulty level, past the least disturbing item (that it was difficult to have windows open during the day). This will limit the reliability of questions about aspects that are slightly disturbing, if you do not, for example, supplement with people who have a higher sensitivity to disturbance.

2. Internal consistency: Does all survey questions about a particular outcome address the same underlying concept?

Although the Rasch analysis seems to indicate reasonable validity in assessing respondent characteristics such as sensitivity or leniency, a principal component analysis (PCA) was made, Figure 9. The result shows a number of variational components, or dimensions, beyond the first order assumption of Rasch analysis of a single parameter, δ.

Three distinct clusters are shown in the so-called loading plot in Figure 16, associated with auditory disturbance and visual disturbance from the wind turbines, respectively, and with general disturbance, according to the PC analysis of the responses to questionnaires].

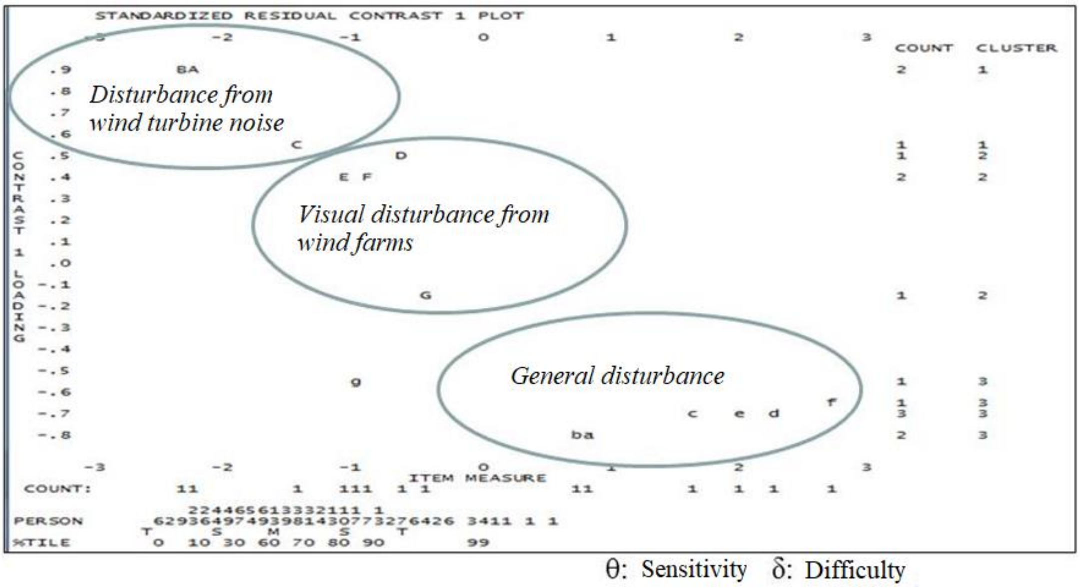

Figure 9 Principal component analysis (PCA loading plot versus difficulty, δ) for psychometric modelling of the respondents' sensitivity to disturbance from wind turbine noise among the 500 individuals [Rasch analysis with eq. 2 applied on the questionnaire answers].

3. Respondent ability (reproducibility): Respondent's consistency in repeated questions (reliability) and coherence between different respondents (validity)

The measurement uncertainties, which are calculated as reliability and validity, are plotted in the various figures in the result section 3.2-3.4.

Measures of (standard) measurement uncertainty in Rasch attribute values for a capability θ and a difficulty δ are given as standard error:

$$\begin{cases} u(\theta) = \sum_{j=1}^{L}\left(P_{success,i,j,k} \cdot P_{success,i,j,k\prime}\right)^{-\frac{1}{2}} \\ u(\delta) = \sum_{i=1}^{N_{TP}}\left(P_{success,i,j,k} \cdot P_{success,i,j,k\prime}\right)^{-\frac{1}{2}} \end{cases} \quad (3)$$

3.7. Measurement / Object Separation and Decision Making

A reliability coefficient (Rz) for Rasch attribute values, z, is calculated by:

$$R_z = \frac{\text{True variance}}{\text{Observed variance}} = \frac{var(z)}{var(z\prime)} = \frac{var(z) - var(\varepsilon_z)}{var(z\prime)} \quad (4)$$

Measurement uncertainties calculated with Equation 4 may have typical values for the reliability coefficient around 0.8 [the figures in section 3.2-3.4.]. At these values, about 50% of the observed variance is only an illusion which is resulting from a limited measurement quality, which, however, is accepted as good enough for so-called "high-stake" decision making [18]. It is a well-known fact that the reliability coefficients for both respondent ability (θ) and object difficulty (δ) are determined partly by (a) the number of respondents and partly by (b) the number of questions, which e.g. can be derived from the Spearman-Brown prophecy formula.

4. CONCLUSIONS

The results of the psychometric analyses showed a large spread in sensitivity to disturbances (both visual and acoustic) from wind power plants among the 606 individuals responding to the questionnaire. However, there was evidence of a weak positive correlation between the individual's sensitivity, θ, to disturbance and their age, but no correlation at all with annual income or general health. A weak positive correlation existed between each individual's sensitivity, θ, to disturbance and the locally measured noise level (L_pA). The most disturbing element was linked to the question: *How do you generally experience the noise level from wind turbines close to your home*? The least disturbing was associated with *difficult to have windows open during the daytime*.

When the survey questions about demographics, attitudes and health were analyzed in terms of each individual's degree of health, θ, and the difficulty, δ, of each health aspect, it was found that the most difficult element with respect to disturbances was linked to the question *Do you have tinnitus*? The easiest was linked to *I'm depressed*.

A formula for predicting an individual's sensitivity to disturbance from wind turbine noise could be derived with PCR analysis.

Despite low response rates for questions about financial compensation from the wind power plants, an analysis could still be performed of each individual's degree, θ, of leniency and each compensation model's degree, δ, of quality. The compensation model that was found to have the highest quality was associated with the question *Has your community benefited from a compensation scheme*?, while the question *Has the wind power plant paid compensation to you*? got the worst quality assessment. No correlation was found at all between the individuals' leniency with the compensation service and the annual income or sensitivity of the individual to disturbance from the wind power plants.

Both the reliability (the respondent's reproducibility) and the validity (the coherence between different respondents) were estimated in these psychometric analyses. It was found that the consistency between the two attributes' distribution in the different sections of the questionnaire could be increased if there were more people with a high sensitivity to disturbance.

5. ACKNOWLEDGEMENTS

We acknowledge gratefully the financial support from Vindval.

6. REFERENCES

1. B. Berglund and T. Lindvall, (Eds.), *Community noise*. Document for the World Health Organisation. Archives of the Centre for Sensory Research, 2, 1–195 (1995)

2. S. A. Janssen, H. Vos, A. R. Eisses, E. Pedersen, *A comparison between exposure-response relationships for wind turbine annoyance and annoyance due to other noise sources*, J Acoust Soc Am. 130(6), 3746-3753 (2011)

3. Swedish Environmental Protection Agency, *Ljud från vindkraftverk* (in Swedish), Report 5933, NV dnr 382-6897-07 Rv, Naturvårdsverket, (2010)

4. E. Pedersen and K. Persson Waye, *Perception and annoyance due to wind turbine noise – a dose-response relationship*, J. Acoust. Soc. Am., 116(6), 3460-3470 (2004)

5. The Public Health Agency of Sweden, *Socialstyrelsens allmänna råd om Buller inomhus*, SOSFS 2005:6 (in Swedish), National guidelines, Stockholm (2005)

6. J. Bass, M. Cand, M. Coles, R. Davis, G. Irvine, G. Leventhall, T. Levet, S. Miller, D. Sexton and J. Shelton, *A Method for Rating Amplitude Modulation in Wind Turbine Noise*, Institute of Acoustics, Amplitude Modulation (2016)

7. Renewable UK. *The Development of a Penalty Scheme for Amplitude Modulated Wind Farm Noise - Description and Justification*, Report (2013)

8. International Standards Organization (ISO), *Acoustics-Assessment of noise annoyance by means of social and socioacoustic surveys*. ISO/TS 15666:2003 (E), ISO, Geneva, Switzerland (2003)

9. G. Rasch, *On general laws and the meaning of measurement in psychology*. In Proceedings of the Fourth Berkeley Symposium on Mathematical Statistics and Probability, IV, 321–334. Berkeley, California: University of California Press. Available free from Project Euclid (1961)

10. L. R. Pendrill, *Assuring measurement quality in person-centred healthcare*, Measurement Science & Technology, Volume 29, Number 3, 034003 special issue Metrologie (2017) https://doi.org/10.1088/1361-6501/aa9cd2

11. E. Svensson, *Guidelines To Statistical Evaluation Of Data From Rating Scales And Questionnaires*, Journal of Rehabilitation Medicine, 33(1), 47–48 (2001)

12. R. W. Massof, *Applications of stochastic measurement models to visual function rating scale questionnaires*, Opthalmic Epidemiology, 12, 1 – 22 (2005) doi: 10.1080/09286580590932789, http://dx.doi.org/10.1080/09286580590932789

13. W. P. Fisher, *Physical disability construct convergence across instruments: Towards a universal metric*, Journal of Outcome Measurement, 1(2), 87 – 113 (1997)

14. D. Andrich, *A rating formulation for ordered response categories*, Psychometrika, 43, 561-73 (1978)

15. G. N. Masters, *A Rasch model for partial credit scoring*, Psychometrika, 47, 149-174 (1982)

16. R. Bakker, E. Pedersen, G. van den Berg, R. Stewart, W. Lok, J. Bouma, *Impact of wind turbine sound on annoyance, self-reported sleep disturbance and psychological distress*, Science of the Total Environment 425, 42–51 (2012)

17. K E Roach, *Measurement of Health Outcomes: Reliability, Validity and Responsiveness*, Journal of Prosthetics and Orthotics, **18**(6), P8-P12 (2006)

18. Linacre, J. M., *Optimizing Rating Scale Category Effectiveness*, Journal of Applied Measurement, *3*(1), 85-106 (2002)