Willingness to pay in the Rhine-Main region according to aircraft noise, railway noise, road traffic noise

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ABSTRACT

This study on willingness to pay (WTP) for noise abatement has been carried out in the Rhine-Main region using survey data from 9,244 participants of the NORAH project (Noise-Related Annoyance, Cognition, and Health), work package 1 "Annoyance and health-related quality of life". The willingness to pay was analyzed by the question "What would you be willing to pay in the next five years for noise reduction in addition to monthly housing costs?". In the analysis 6,330 valid responses were considered. For each respondent the willingness to pay was related to individual levels of aircraft, road traffic and railway noise exposure and to their energetic summation as well as to the individual level of annoyance stated according to the ICBEN scale. The range of the amount of WTP is actually high and the values show a great spreading. Thus, there is hardly a dependency between WTP and sound level. For annoyance a weakly linear dependency of the WTP was found. However, there is still a WTP even if there is no annoyance. The WTP does not seem to reflect the willingness to pay for a less noisy own flat or house. Instead of this, the WTP in this study may show the willingness to pay for a less noisy environment at all.

Keywords: Social costs of noise, Willingness to pay, Aircraft noise, Road traffic noise, Railway noise
I-INCE Classification of Subjects Number(s): 66.2, 67.4

1. INTRODUCTION

Noise, especially traffic noise, causes annoyance, disturbances and even can induce diseases. A large number of studies e.g. (1, 2, 3, 4) confirm the annoyance reactions due to aircraft, road traffic and railway noise. The living quality in residential areas diminishes.

Especially nocturnal noise causes sleep disturbances. In many labor and field studies the decrease in sleep quality and the increase of the probability of awaking due to nocturnal traffic noise was shown e.g. (5, 6, 7).

Long-term exposure to transportation noise has been associated with a higher risk for some diseases. It was shown that noise can cause cardiovascular disease e.g. (8, 9, 10, 11), diabetes e.g. (12), obesity e.g. (13) and hypertension e.g. (14). In the framework of LARES (e.g. 15) and HYENA (e.g. 16) noise induced annoyance and the risk of some disease were investigated. In (17) increased risks for cardiovascular and psychiatric disorders are reported.

In the last few years (2011 to 2015) in context of the NORAH study (Noise-Related Annoyance, Cognition, and Health) the effects of aircraft, road traffic and railway on health and living quality of the noise affected population were investigated (cp. the final reports of the study, 18). In the different modules of the study results concerning annoyance and disturbance, nocturnal awakenings and sleep quality as well as an increase in the risk of disease were reported.

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Noise does not only lead to a reduced quality of life and an increase in risks of diseases, it also costs money: The total costs of the noise are often quantified by the noise-induced depreciation of real estate or rent failures and costs accompanied by noise-related health effects. Most studies concerning the costs of noise show the dominance of depreciation of real estate or rent failures; usually they are responsible for approx. 80 % of the traffic noise costs (cp. 19).

For the implementation of the European Noise Directive, especially for the therein required estimations of cost-benefit-ratios for noise abatement measures, Navrud (20) did a review of property value studies regarding the impact of noise. He introduced the NSDI (Noise Sensitivity Depreciation Index) as a measure of the loss of estate value due to noise. The NSDI is a parameter which shows the percentage change of house prices per dB increase in noise level. However, the specified values for the NSDI are very different in the evaluated studies. The different values are caused by different study designs and strong regional differences. Some studies implemented in the evaluation are very old; first studies were conducted in the 1960-ies. Newer studies for example from the Netherlands (21), Switzerland (22), Sweden (23) or Korea (24) confirm the decrease of property value due to traffic noise; however the reductions are not unique.

The primary aim of this study was to give statements on the noise related decrease of property value for the Rhine-Main region. Therefore the method of evaluating the willingness to pay (WTP), a method belonging to the contingent valuation methods especially used in environmental economics, was used. Thereby the willingness to pay is a measure of the appreciation of the environmental good asked for, here for the improvement of a noisy situation. Thus the not commercially available goods “silence” or “noise reduction” are made “acquirable”.

The investigations were carried out in the context of the NORAH study (25, 26).

2. MONETARY VALUATION APPROACHES

Essentially two different methods based on the evaluation of preferences are used to evaluate the monetary impacts of noise on property values. The methods are used to evaluate the values of goods for which no market prices exist such as noise resp. silence.

By the direct method, the appreciation for certain goods resp. levels of environment is determined by questioning. Hereby the contingent valuation method (CV) is common: Test persons are asked for their preferences in interviews. Hypothetical markets are presented to them as well as the information which is necessary to allow a valuation of the goods resp. levels of environment. The result is the amount a person is willing to pay. There is a difference between the willingness to pay for an improvement of an environmental condition, leading to a lower amount of the value of the good and the willingness to accept, corresponding to a payment of compensation, normally leading to a higher amount of the value of the good.

By the indirect method, the preferences for environmental goods are determined from the observed behavior of individuals to real existing markets and from their revealed value estimates.

One of the most common indirect methods is the hedonic pricing (HP). This method deduces the preferences for a good traded on the market to the preference for an environmental good. The method belongs to the revealed preferences methods. By regression analysis the influence of individual parameters on the property prices can be determined. Hedonic pricing was used for monetary valuation of traffic noise in recent years.

3. DATA DESCRIPTION

3.1 Participants

9,244 participants of the NORAH project, work package 1 “Annoyance and health-related quality of life”, are included in this study.

The participants live in a study area including municipalities within the envelope of the 40-dB-noise level contour of air traffic noise for day and night.

In the analysis of the WTP 6,330 valid responses were considered, i.e. 68.4 % of the sample. 2,914 participants gave responses without a willingness to pay (called “protester”): for 920 participants (10.0 %) out of the protester the polluter is responsible and has to pay, 334 (3.6 %) thought that the government is responsible (for example noise abatement by taxes), 179 (1.9 %) did not see any possibility for additional noise prevention, 1,481 participants (16.0 %) did not mention any reason for their denial to pay. 4,835 (52.3 %) participants were willing to pay (at least 1 €). 616 (6.7 %) do not have any money left caused to high rental prices or unemployment. 613 did not feel disturbed and 258 mentioned any other reasons. Figure 1 shows the distribution.

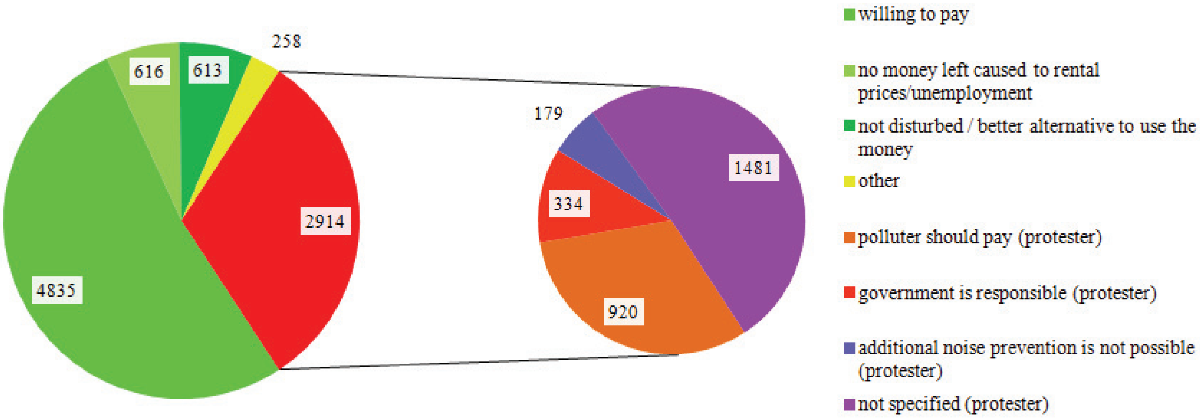

Figure 1 – Distribution of participants according willingness to pay

The statistical dataset includes gender and age as well as information about the monthly household income. 46.9 % of the participants are male, 53.1 % are female, and the age covered a range from 18 to 96 years with an average age of 49.5 years.

The monthly income per household was enquired in groups, see table 1, which also gives the distribution (on the basis of 5,408 given answers out of the 6,330 valid WTP responses):

Table 1 – Monthly income per household

Income group	Income in €	Number of households	Percentage
1	< 1,250	331	6.1
2	1,250 – 1,750	428	7.9
3	1,750 – 2,250	663	12.3
4	2,250 – 3,000	1,002	18.5
5	3,000 – 4,000	1,219	22.5
6	4,000 – 5,000	850	15.7
7	> 5,000	915	16.9

In comparison to the income distribution in Hesse in this part of the NORAH study the lower income groups (up to 2,250 €) are underrepresented, and the higher income groups (over 3,000 €) are overrepresented, which might reflect either a sample bias with regard to the income or a deviation of the income of the population in the study region compared to the total population in Hesse.

3.2 Acoustics

By the NORAH Consortium the following acoustical data were made available (see 25):

Table 2 – Sound level

Noise source				
Air	L_{pAeq}, day (6-22 h)	L_{pAeq}, night (22-6 h)	L_{pAeq}, 24 h	L_{DEN}
Road	L_{pAeq}, day (6-22 h)	L_{pAeq}, night (22-6 h)	L_{pAeq}, 24 h	L_{DEN}
Rail	L_{pAeq}, day (6-22 h)	L_{pAeq}, night (22-6 h)	L_{pAeq}, 24 h	L_{DEN}

All sound levels refer to noise exposure over 12 months (10/2010-09/2011).

Individual aircraft noise levels were calculated according to the guidelines for calculations for noise abatement zones (AzB, 27) by the direct use of radar data. The noise levels were calculated for the center of area for each building according to AzB (27).

The noise levels for road traffic and railway noise were calculated according to the VBUS (28), VBUSCH (29) and VBEB (30) used in the context of the European Noise Directive (END). For all facades of each building facade noise levels were calculated at a height of 4 m. The maximum of the value was chosen as the noise level for the building (25).

In urban situation, a person often is affected by more than one traffic noise source. For the investigation the dominant source was selected by a criterion of dominance of 2.5 dB. For example railway noise is the dominant noise source if its sound level is at least 2.5 dB higher than the level of aircraft noise as well as road traffic noise.

The “total” sound level is given by energetically addition of the sound levels of the single noise sources. Thereby for road traffic noise and railway noise the maximum level per building is used. Thus in some cases the real noise situation is overestimated.

In this first step of the investigation only the average sound levels caused by aircraft, road traffic and railway during day time (6.00-22.00 h) were included.

The continuous aircraft sound levels for daytime 1,488 participants are exposed to range from 36.6 to 62.2 dB(A), for road traffic noise the continuous sound levels 2,705 participants are exposed to range from 30.0 to 80.6 dB(A), for railway noise the continuous sound levels 447 participants are exposed to range from 30.0 to 79.0 dB(A) and for total transportation noise the continuous sound levels range from 38.1 to 80.6 dB(A).

The distribution of the average sound levels for the 6,330 participants with valid responses is given in figure 2.

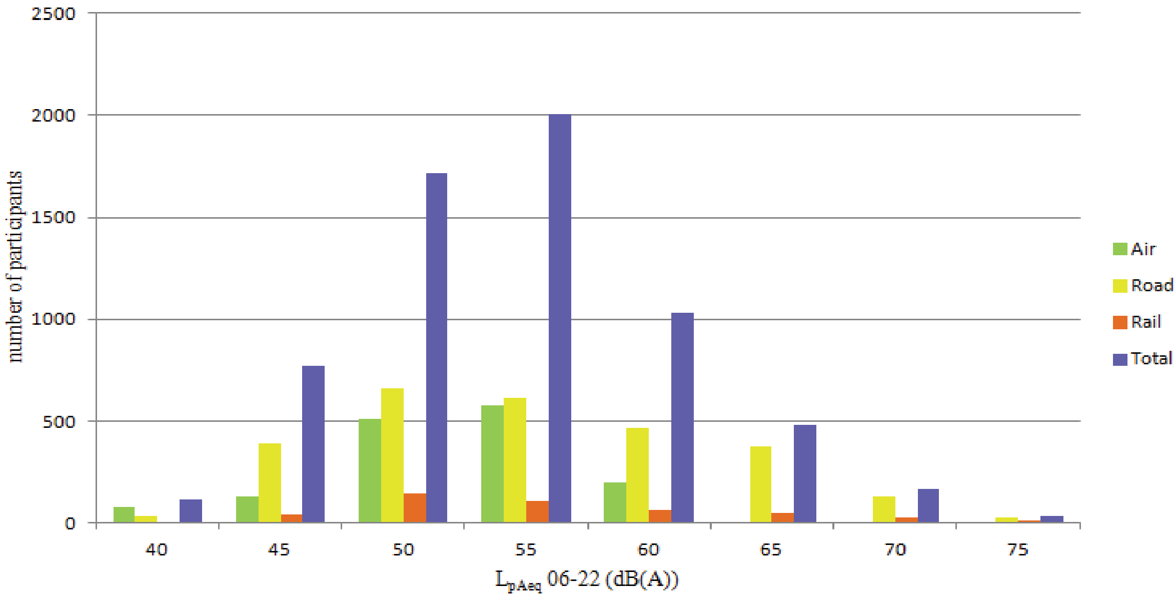

Figure 2 – Distribution of average sound levels

The high numbers of participants for “total” noise are due to the fact that in this noise group persons are included who are affected by more than one noise source but none of the noise sources is dominant.

3.3 Willingness to pay

Willingness to pay was analyzed by the question "What would you be willing to pay in the next five years for noise reduction in addition to monthly housing costs?". The participants could give additionally remarks and reasons if they were not willing to pay for noise abatement. In the analysis the answers of the protester (figure 1) were not considered.

The WTP ranges for aircraft noise from 0 to 1,000 €, for road traffic noise from 0 to 2,000 € and for railway noise from 0 to 500 €. The maximum value for WTP was 5,000 € (no dominance of a noise source).

Furthermore the answers to the statements: "It is the right of every person to live in a quiet living environment with no or only few noise." and "It is luxury and only possible for rich people to live in a quiet living environment." were collected. The evaluation of these questions will be presented elsewhere.

All interviews were performed by trained interviewers, usually by telephone, in the framework of the NORAH study.

3.4 Annoyance data

The WTP-analysis was based on the average sound levels in a first step. But additionally analyses based on levels of annoyance were performed. In the context of NORAH the annoyance due to aircraft, road traffic and railway noise was surveyed according to the standard ICBEN scale. These data and the resultant highly annoyed data (%HA, i.e. percentage of persons using the two upper categories of the 5-point ICBEN scale) were also used in the analysis (26).

4. METHODS

All data were placed at the disposal by the NORAH consortium. The data were made anonymous. The attribution of the data was carried out by a thirteen-digit ID.

The analyses are based on the L_{pAeq}, day (6-22 h) for aircraft noise, road traffic noise and railway noise and the L_{pAeq}, day (6-22) as sum of the three mentioned noise types, the "total" transportation noise.

In a first step the direct linear dependence between willingness to pay and L_{pAeq} as well as between willingness to pay and annoyance was surveyed. In figure 3 all raw data, expect WTP over 500 €/mo., are shown in a point chart. The concentration of WTP is very high between 0 and 50 €/mo. in a range of 42 to 72 dB(A), for "total" transportation noise. WTP over 50 €/mo. is concentrated on round numbers such as 100 or 200 €/mo. The plotted linear regression proceeds almost parallel to the abscissa.

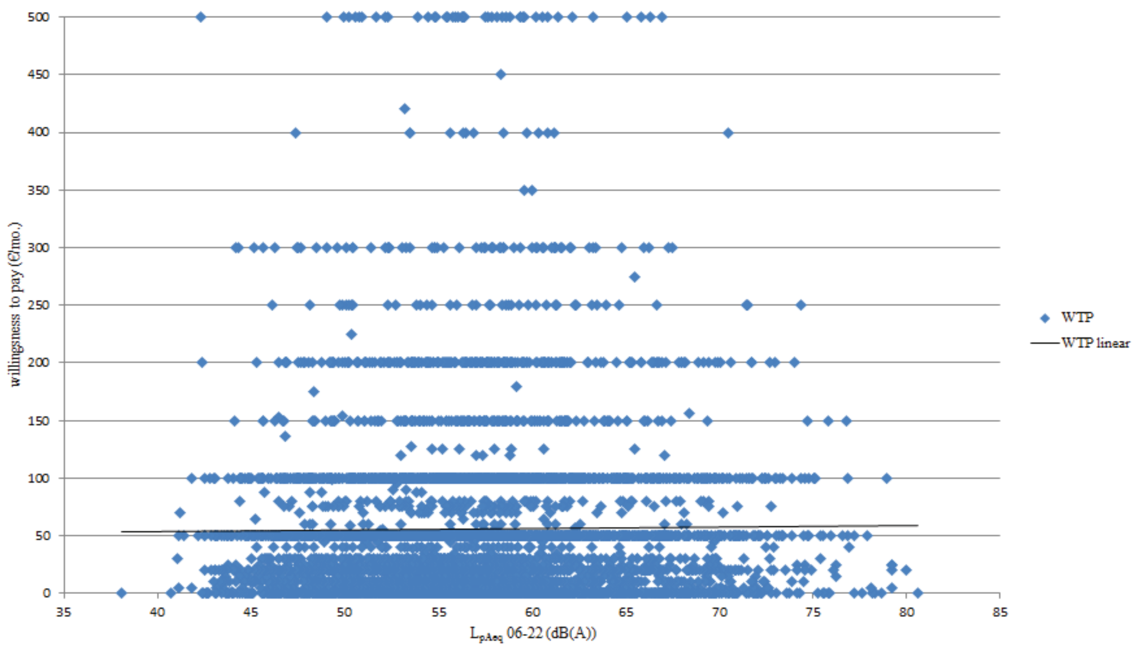

Figure 3 – WTP according to sound level ("total" transportation noise, raw data)

WTP was plotted in dependency on the sound level for aircraft noise, road traffic noise and railway noise, too. In a linear model the R^2 for air traffic noise is the highest one of these traffic noise sources, but with 0.0068 there is no evidence for a liner dependency.

Figure 4 shows the scatterplot of the association between annoyance and WTP. The slope of the plotted linear regression is 10.18 €/mo. per annoyance level.

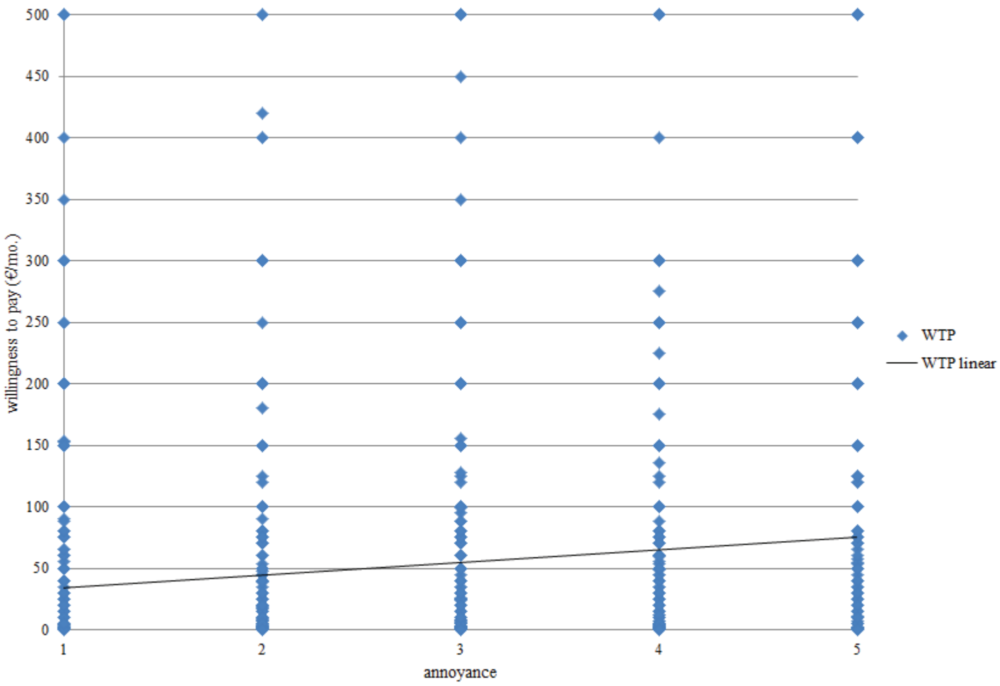

Figure 4 – WTP according to annoyance (raw data)

To find out if the WTP correlates linearly with the L_{pAeq} or with the annoyance the mean value ($\bar{X}$), the standard deviation (S), the coefficient of determination (R^2) and the Pearson correlation coefficient (r) were computed (table 3).

Table 3 – Linear model WTP and L_{pAeq} and WTP and annoyance

	$\bar{X}$ [€/mo.]	S [€/mo.]	R^2	r
WTP to L_{pAeq}	56.08	107.07	0.0001	0.01
WTP to annoyance	56.07	106.19	0.0164	0.13

The high standard deviations illustrate the strong scattering of the WTP around the mean value of 56 €. The coefficient of determination and the Person correlation coefficient for the dependence between the WTP and the L_{pAeq} are nearly zero. A direct linear relation does not exist between WTP and L_{pAeq} in the raw data.

The Pearson correlation coefficient and the coefficient of determination are a bit higher for the relation between WTP and annoyance. Nevertheless both coefficients are close to zero. A linear correlation between WTP and annoyance cannot be verified.

To find out if the WTP depends in any other way on the L_{pAeq} or the annoyance the data were grouped to perform the chi square test. The WTP was divided into steps of 50 €, up to 250 €. Higher WTP was summarized in the last group. The sound level were divided in groups by steps of 5 dB(A) (from 40 to > 60 dB(A)).

Table 4 – Chi-Square test for WTP vs. L_{pAeq} and WTP vs. annoyance

	α	F	p	χ^2
WTP to L_{pAeq}	0.05	20	0.560	34.163
WTP to annoyance	0.05	20	0.000	281.430

(α = error probability, F = degree of freedom, p = p-value, Chi^2 = test statistic of chi square test)

The null hypothesis was that the WTP does not depend on L_{pAeq} or annoyance. For the analysis between WTP and L_{pAeq} the null hypothesis is accepted. The p-value (0.560) is greater than the level of significance (α = 0.05). WTP does not depend on the L_{pAeq}. For the analysis between WTP and annoyance the null hypothesis is rejected, because the p-value (0.000) is smaller than the level of significance (α = 0.05). The WTP depends on the annoyance.

For the further analysis the sound level groups of 5 dB were kept. The mean value of the WTP was calculated for each sound level group and for each annoyance level. The results are shown in the next chapter.

5. RESULTS

As shown in chapter 4 no linear dependency between WTP and sound level could be observed. Nonetheless, if the data are arranged according to sound level groups (groups of a range of 5 dB from 40 to > 60 dB were chosen) a slight linear trend could be seen between the WTP and the sound levels for all noise sources, with the highest slope for air traffic noise and the smallest one for the "total" noise. However, according to these trend lines a WTP of 0 € would appear for sound levels much lower than the background noise. Furthermore, the standard deviation of each WTP value is enormous. Thus, this slight linear trend should not be overestimated.

As mentioned above WTP and annoyance are interdependent. The mean values of the WTP show a linear dependency on annoyance. In figure 5 the total WTP in €/mo. depending on the annoyance level is given. The annoyance is scaled according to ICBEN from 1 to 5.

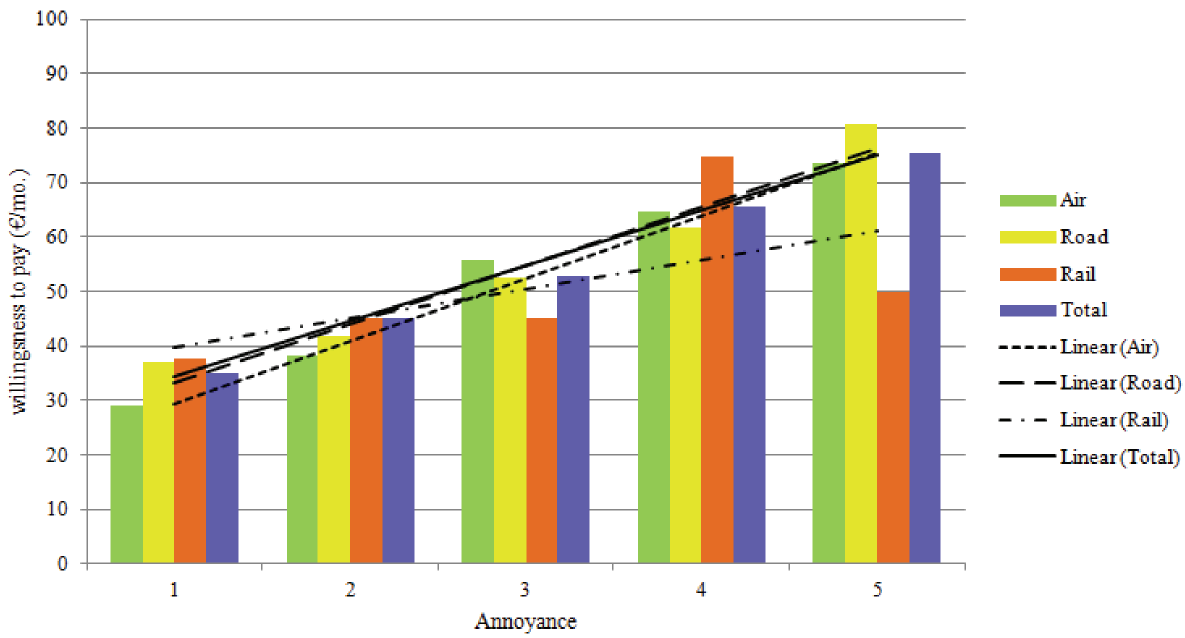

Figure 5 – WTP according to annoyance

The WTP values in the bar chart are the mean values for each noise source for each degree of annoyance. However, the standard deviation of each WTP value shown in the figure is enormous.

Here a linear dependency of the WTP becomes apparent: Except for railway noise the WTP increases strictly with an increase in annoyance. For railway noise an increase is seen by trend. There are no significant differences in the WTP according to the source of noise.

Table 5 shows the slope and the coefficient of determination for the mean values of the different noise sources.

Table 5 – Linear model WTP and annoyance

Noise source	Slope [€]	R^2
Air	11.54	0.983
Road	10.72	0.953
Rail	5.40	0.361
Total	10.15	0.996

Thus the annoyance seems to be a better predictor for the WTP than the sound level. This is understandable: The more a person is annoyed the more he or she is willing to pay for an improvement of the situation.

Due to the enormous scattering of the absolute WTP (in €/mo.) the question appeared if it is useful to ask for the WTP as percentage of income in future surveys. Therefore the WTP in relation to the income was computed. In higher income groups the WTP in relation to the monthly income declines. This trend shown in figure 6 for “total” noise, can also be seen for single aircraft, road traffic and railway noise in the upper sound levels.

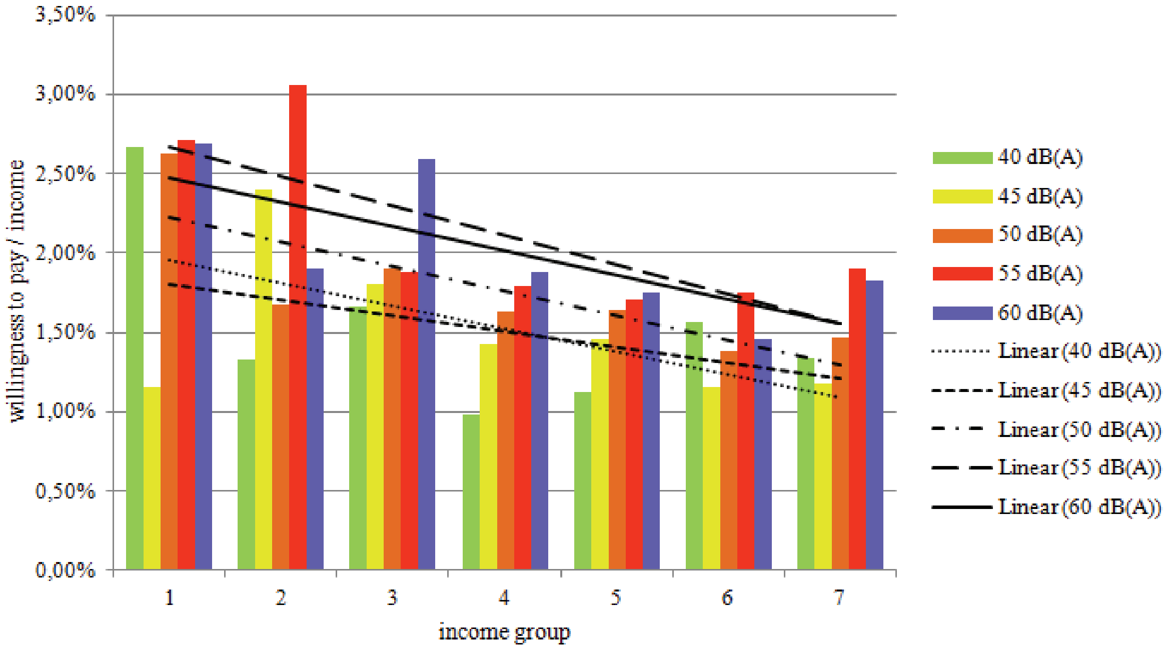

Figure 6 – Relative WTP according to income

In table 6 the %HA for every income group is shown. The percentage of highly annoyed people in the income classes 1 and 2 is a bit lower than in the other income classes. Although less people are highly annoyed in those classes the willingness to pay in relation to the monthly income is higher.

Table 6 – %HA in different income groups

Income group	1	2	3	4	5	6	7
%HA	38.7	38.0	41.3	44.4	44.7	46.4	43.3
% not HA	61.3	62.0	58.7	55.6	55.3	53.6	56.7

To ask for the WTP in relation to the monthly income might have some advantages in comparison to the absolute WTP. Unrealistic outliers might be avoided and the differences between the income groups concerning the WTP in relation to the income might be adapted.

6. DISCUSSION

The valuation of the WTP is enormous: It ranges up to 5,000 € per month (1 participant); 12 participants declared values of 1,000 € or more. Such high values seem to be unrealistic.

The WTP does not show any linear dependency on sound level in the raw data. By establishing sound level groups and calculating mean values of the WTP for each sound level group slight linear trends appear.

The investigations show an increase in the willingness to pay for each noise source according to the annoyance level. However, the sound level resp. annoyance (alone) is not a good predictor for the WTP. The willingness to pay for the own living quality cannot be described by single parameters. Other influencing factors have to be considered in the model.

Furthermore, the inquired WTP does not seem to reflect the willingness to pay for a less noisy own flat or house. The inquired WTP in this study may show the willingness to pay for a less noisy environment at all. The WTP for the own living quality should tend to zero for sound levels which are comparable to (urban) background noise or for the annoyance level 1 (not annoyed at all). An interpretation of the revealed WTP in relation to the decrease of property values does not seem to be possible.

In the interpretation of the WTP according to the grouped sound level the small numbers of participants in the lowest sound level classes (aircraft: 77, road traffic: 34, railway: 3) has to be taken into account. The increase of the amount of WTP is not very high at all. One reason could be the consideration of low sound levels (down to 40 dB(A)); NSDI normally starts at 50 or 55 dB(A)). On the other hand using the sound level of the facade with the highest noise pollution for the whole building and using the energetic addition of the sound levels to "total" sound levels overestimates the noise exposition in some cases; thereby the WTP may be underestimated.

The WTP in this analysis cannot be used as a quantity showing the decrease of house pricing and rents. Therefore a NSDI could not be calculated from these data.

It should be kept in mind that the survey was conducted in 2011, at a time a high awareness to noise due to the discussion about the opening of the new landing runway and the prohibition of night flight operation could be noticed in the Rhine-Main region.

7. CONCLUSIONS

According to the enormous range of the revealed WTP the total amount of WTP does not seem to be the appropriate measure in a survey. Maybe it is more appropriate to use the relative WTP, relating to the household income, instead.

As in noise annoyance studies potential confounders should be included in the model.

In this investigation only the daily sound level was used as an acoustical parameter; the relation of the WTP with the other acoustical parameters should be investigated, too. However, it seems that WTP better fits with annoyance than sound level.

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30. Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit und Bundesministerium für Verkehr, Bau und Stadtentwicklung. Bekanntmachung der Vorläufigen Berechnungsmethode zur Ermittlung der Belastetenzahlen durch Umgebungslärm (VBEB), 9. Februar 2007; BMU-Az. IG I 7-41008/5.