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ASSESSMENT OF ANNOYANCE IMACT OF ROAD NOISE SOURCES UNDER THE LABORATORY CONDITIONS

14.1 INTRODUCTION

Problem of annoyance of noise sources occurs not only in the place of residence, but also in the external environment and work environment. Research results, among others [3, 5] are focused on linking psychoacoustic measures of sound quality with quantitative noise indicators. The subjective aspect of the perception of sounds as well as the multiplicity of factors accompanying the perception process caused, that has not been developed and widely used model for assessing the noise annoyance. Applied approaches are limited to the perception of sound in time in a variable layout: the source-path of the propagation-receiver, taking into account the variable subjective and external characteristics. The paper attempts to apply statistical analysis methods in determining the significance of the selected input variables to assess the annoyance impact of traffic noise sources.

14.2 THE USE OF THE STATISTICAL METHOD IN THE ASSESSMENT OF NOISE ANNOYANCE

Within a laboratory experiment, the author carried out the assessment of noise annoyance of the impact of the road noise sources to the urban environment. During the experiment, acoustic signals from 30 samples were randomly issued. The acoustic signals were emitted from two stereo speakers. There was applied the method of scaling the scores (one by one) in the range of from 1 to 5. The experiment involved 80 people aged between 22-50 years.

14.2.1 Acquisition and selection of data

The choice of the statistical evaluation method is determined on the one hand by the form of sets of quantitative and qualitative data, on the other hand the possibilities of its application. Within undertaken own research there were acquired and generated data sets of the parameters that determine the effects of the impact of road noise sources. In particular, as part of the measurements in the urban environment, there was obtained following the data corresponding to acoustic events in time:

- balanced sound level values LeqA,
- recorded audio waveforms of acoustic signals,
- types of noise sources for occurring noise events,
- types of surfaces for moving noise sources.

In order to determine sound quality measures, the received audio waveforms required the use of appropriate methods [1, 2] for data processing and analysis. The basic but not the only psychoacoustic measure of the annoyance assessment of time-varying sounds is the loudness, which is a standardized measure (DIN 45631/A1:2010 – Zwicker method). Other measures such as: sharpness (S) or tonality are standardized only for stationary signals. Additional measures, ie roughness (R) and fluctuations strength (F) They are determined based on the adopted procedures, but they are not standardized measure. The values of the particular measures were determined by the use of Zwicker and Aures methods [1, 2]. Proposed assessment of noise annoyance [7] consists in determining objective annoyance (UBA). The UBA formula is used in cases of impact of different noise sources [5], which objectively represents the relationship of subjective sound quality measures. Objective annoyance is defined as a combination of measurement: sharpness, fluctuation strenght, loudness (N10 – ten percentile value) corrected by the period of the day:

$$UBA = d(N_{10})^{1.3}\left[1 + 0.25\cdot(S-1)\log(N_{10}+10) + 0.3\cdot F\left(\frac{1+N_{10}}{N_{10}+0.3}\right)\right] \tag{14.1}$$

where:

d= 1 – for the time between the 22:00-6:00,

d= $1+\left(\frac{N_{10}}{5}\right)^{0,5}$ – for the time between the 6:00-22:00

Proposed by [5] corrected formula UBA as psychoacoustic annoyance (PA) is a combination of loudness (N5 five – percentile value), fluctuation strenght and roughness – with respect to sharpness.

$$PA = N_5\left(1+\sqrt{{w_s}^2 + {w_{FR}}^2}\right) \tag{14.2}$$

For S>1.75

$$w_s = (S-1.75)\cdot 0.25\lg(N_5+10) \tag{14.3}$$

For S≤1.75

$$w_{FR} = \frac{2.18}{N_5^{0.4}}(0.4F + 0.6R) \tag{14.4}$$

After substituting to (14.1, 14.2, 14.3, 14.4) in Table 14.1 there was summarized fragmentary range of variables for an ordered set of samples corresponding to the test points being measured.

Quantitative and qualitative data, presented in the Table 14.1, are a set of inputs to the statistical assessment of the noise annoyance. Variable marked Zmn1 represents average values of the noise annoyance ratings obtained from the experiment.

Table 14.1 Fragmentary range of input variables

	Input variables									
	Zmn1	**Zmn2**	**Zmn3**	**Zmn4**	**Zmn5**	**Zmn6**	**Zmn7**	**Zmn8**	**Zmn9**	**Zmn10**
Sample	sr._odp	N	S	R	F	UBA	PA	r. źródła	naw.	LeqA
1	4,63	2,65	1,4	0	0,46	6,63	4,72	2os	bruk	56
2	4,55	2,57	1,5	0,1	0,48	6,51	4,80	2os	bruk	56
3	4,65	2,87	1,2	0	0,33	6,61	4,74	aut	bruk	56
4	4,56	2,71	1,2	0	0,18	7,01	4,65	2os	bruk	56
5	4,75	2,83	1,4	0	0,26	6,03	4,11	2os	bruk	56
6	4,41	2,92	1,5	0	0,14	8,60	5,16	os	bruk	56
7	3,83	4,66	1,3	0,1	0,3	13,54	7,86	2os	asfalt	62

Source: own elaboration based on [1, 2, 5]

In the Table 14.2 there was presented fragmentary set of statistical parameters corresponding to the variable Zmn1 and sample numbering.

Table 14.2 Fragmentary set of statistical parameters for Zmn1

Sample	Median	Kurtoza	Standard deviation
1	5	0,90	0,60
2	5	0,07	0,61
3	5	1,11	0,58
4	5	2,23	0,65

Source: own elaboration based on [6]

14.2.1 The use of the method Anova

The idea of variance analysis is to compare the dispersion of dependent variable in the studied groups separated by the values of independent variables. Analysis of variance allows us to assess the relevance of effects, ie the influence of one independent variable on one dependent variable and the interaction of independent variables, having a significant impact on a given dependent variable. Annoyance assessment was carried out with the use of the using Anova's main effects. Research on quantitative variables affecting noise annoyance [3, 5] shows, that in addition to the psychoacoustic variables, a significant impact not only has the same value L_{eqA}, but the structure of its shaping in time. To the dependent variables there was included the parameters of the sound quality assessment and averaged assessments of the annoyance received from the laboratory experiment. Independent variables are assumed as qualitative variables ie. the type of the source and the type of surface with using the method Anova, which are important not only in the noise immision, but they affect the spectral distribution. A variance analysis was performed for three variants of dependent and independent variables (Table 14.3). The independent variables were considered for the following cases:

- source type: passenger car, 2 passenger cars, bus, which corresponds to: *r.źródła={os., 2os., aut.}*
- surface: asphalt, surface and assigned, which corresponds to; *naw. ={bruk, asfalt}*

Table 14.3 Breakdown of variables

Variant no.	Dependent variables	Independent variables
Variant 1	N,S,R,F, LeqA	r.źródła, naw.
Variant 2	sr._odp., LeqA	r.źródła, naw.
Variant 3	UBA, PA, LeqA	r.źródła, naw.

Source: own elaboration based on [4]

For adopted variants, a variance analysis of the main effects was applied. Multivariate significance tests were performed (Wilks test) taking into account parameterization with sigma constraints and decomposition of effective hypotheses for independent variables.

The Table 14.4 shows, that the results of test F for variants of the variance of independent variables do not show the high significance of differentiation of medium-sized study groups.

Table 14.4 Multivariate significance tests (input data)

Variant no.	Variables	Value	F	Efect df	Error df	p
Variant 1	r. źródła	0,659	1,018	10	44	0,443
	naw	0,844	0,809	5	22	0,555
Variant 2	r. źródła	0,781	1,643	4	50	0,177
	naw.	0,961	0,497	2	25	0,614
Variant 3	r. źródła	0,731	1,351	6	48	0,253
	naw.	0,797	2,034	3	24	0,135

Source: own elaboration based on [4]

The shaping of the dependent variable UBA relative to the independent variable – surface does not show any significant differences in the type of surface (Fig. 14.1).

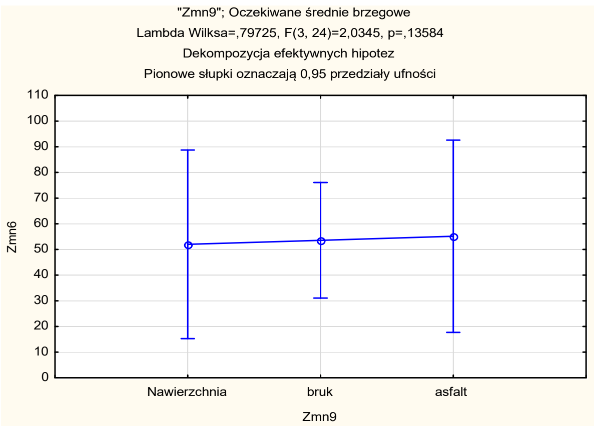

Fig. 14.1 Shaping the average UBA variable depending on the type of surface

Source: own elaboration based on [4]

Analysis of the dependent variable UBA (Fig. 14.2) with reference to the category of independent variable – source type shows categorial differentiation and for source: os is the largest.

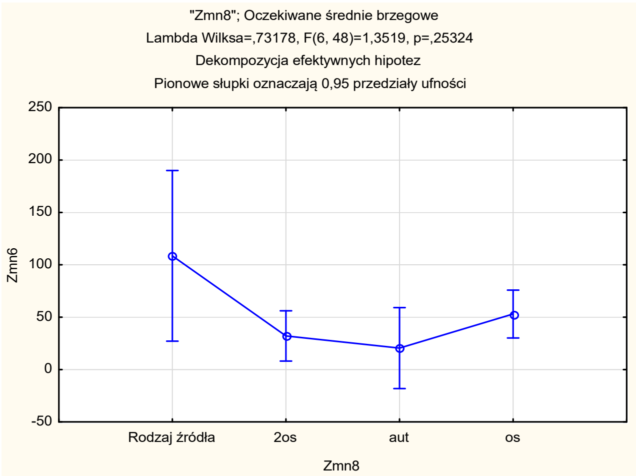

Fig. 14.2 Shaping the average UBA variable depending on the source type

Source: own elaboration based on [4]

The results of variance analysis for the dependent variables (Table 14.5) in the studied groups have a high significance for the parameters of sound quality and for annoyance ratings received from the experiment. The less statistical significance is variable PA, and the smallest UBA. Values of test statistics of the distribution *F* for the significance level α = 0.05 in most cases of dependent variables have values p < 0,05 and their variability is statistically different. Only in the case of variable UBA, value *F* is closer to unity and p > 0,05, which means that there is no basis to reject the null hypothesis.

Table 14.5 Multivariate significance tests (input data)

Variant no.	Variable	SS Model	MS Model	df Model	F	p
Variant 1	N	8688,3	2172,0	4	97,1	0,000
	S	9541,8	2385,4	4	19116,6	0,000
	R	9807,6	2451,9	4	25501,6	0,000
	F	9808,2	2452,0	4	129504,4	0,000
Variant 2	sr_odp.	9223,8	2305,9	4	2114,1	0,000
Variant 3	UBA	8925,3	2231,3	4	1,63	0,195
	PA	8211,1	2052,7	4	13,6	0,000

Source: own elaboration based on [4]

14.3 CONCLUSION

The use of the Anova method in assessing the noise annoyance of traffic noise sources enabled to include quantitative and qualitative input variables. In the study, there was carried out the variant analysis for different variables configuration, taking into account noise annoyance scores obtained in the laboratory experiment. The analysis of input data shows, that the most important influence on the development of sound quality measures is the type of noise source. On the other hand, the most significant impact of the road surface was recorded in the assessments obtained from the experiment. Statistical analysis showed that the lowest significance has UBA measure on the type of the source and type of surface. Due to the varied input data, the proposed method of the variant approach to the assessment of noise annoyance allows for statistical estimating the significance of the input parameters. The obtained results can be applied in the selection of input variables with using intelligent methods of assessing the annoyance impact into environment. It is assumed, that this will allow for a quantitative limitation of noise annoyance research under laboratory conditions.

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Abstract: *The article presents an attempt to statistical assessment of the results of psychoacoustic studies of the experiment carried out on the annoyance of road noise sources. The study was subjected to noise annoyance assessment of emitted acoustic signals under laboratory conditions. The obtained results may be used in the acoustic quality modeling the acoustic quality of the urban environment at risk of noise.*

Key words: *variance analysis, noise annoyance, road noise*

OCENA DOKUCZLIWOŚCI ODDZIAŁYWANIA ŹRÓDEŁ HAŁASU DROGOWEGO W WARUNKACH LABORATORYJNYCH

Streszczenie: *W artykule przedstawiono próbę oceny statystycznej wyników badań psychoakustycznych z przeprowadzonego eksperymentu nad dokuczliwością źródeł hałasu drogowego. Badaniu podlegała ocena dokuczliwości hałasowej emitowanych sygnałów akustycznych w warunkach laboratoryjnych. Otrzymane wyniki badań wykorzystane mogą być w zadaniach modelowania jakości akustycznej środowiska zurbanizowanego zagrożonego hałasem.*

Słowa kluczowe: *analiza wariancji, dokuczliwość hałasu, hałas drogowy*