SURVEY ON LOUDNESS, ANNOYANCE AND LeqDN, AND FACTORS THAT EXPLAIN MOST OF THE VARIANCE OF THE VARIABLES

PACS Reference: 43.50.Rq

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ABSTRACT.

From a social survey and measurements made in order to assess the association between LeqDN, perception of loudness of noise and annoyance we have found a good correlation between LeqDN and perception of loudness. We have also applied factorial analysis to the set of variables and have obtained factors that explain most of the variation of them. The first component is related to the subjective long time impression of the environmental noisiness; the second component is related to the dose of daily experience of annoyance principally due to generic noise sources; the third component is related to identifiable noise annoyance sources of road transportation, which have a considerable acoustic energy. This study was made in a medium size city of South America.

INTRODUCTION.

The percent of highly annoyed persons exposed to environmental noise has been related to annoyance [1]. Nevertheless the real dosage-effect may vary considerable with the measured LeqDN outside the dwellings due to the differences of sound isolation and room distribution of them. Thus, the analysis of different noise perception variables and annoyance variables indexed to measurements of noise are presented. This is an invitation to search for the fundamentals variables that intervene in the explanation of loudness perception and annoyance. This work was carried out in the city of Valdivia, which has 136.000 inhabitants. The city hasn't have problems of railroad or aircraft noise.

RESEARCH METHODOLOGY.

Acoustic Survey.

A noise map of the city was built. A 400 x 400 m grid was aleatorily superimpose in the map of the city to determine the measurement points. The measuring points correspond to the vertex of

the squares. A total of 115 measuring points were established in the city.

During one week a 24-hour sampling schedule was devised to determine measuring periods on the working days of the week. Measurements were made in a representative point of the city. Seven measuring periods were established in the following time hours; 07:00 to 11:00, 11:00 to 14:00, 14:00 to 18:00, 18:00 to 22:00, 22:00 to 01:00, 01:00 to 04:00 and 04:00 to 07:00.

From 07:00 to 22:00 the one minute Leq(A) in each period is fairly constant. From 22:00 to 04:00 there is constant decay of the one minute Leq(A) of 2.5 dB/h. As a 20 minute Leq(A) was measured as a representation of each period, measurements made in time hours between 22:00 – 04:00 hrs. were corrected adding -2.5 dB, 0 dB or +2.5 dB, depending if the measurement was made at the beginning, middle or end of the period. Care was taken in measurements made between 04:00 and 07:00 so to have representative values.

Noise level measurements were made according to ISO 1996-2. All measurements were made with a portable integrating sound level meter Quest 1400, previously calibrated and checked in each measurement. Measures where taken under fair weather conditions and always with a windscreen attach to the microphone.

Social Survey.

The social survey design has taken account the recommendations of Fields [2]. It is considered as population of the survey all the people who live in the city and are older than 14 years old. The sample mark considered all the dwellings of Valdivia and these were selected by means of a systematic sampling [3].

The questionnaire was administered to only one person of the population in the selected dwelling, chosen at random by them. The questionnaire was left at least two days in the dwelling with the aim to give equal opportunity of participation to all members of the house including those who are not at home when the questionnaire is delivered.

The minimum number of questionnaires necessary to obtain a representative sample with a confidence interval of 95% and a significance level of 5% was calculated according to Santos et al. [4]. The minimum sample size is 383 for this population. The final sample size obtain was 473 from a set of approximately 700 questionnaires delivered in all the dwellings at a distance not further than 50 m from the measuring point. Every questionnaire delivered was indexed to the noise measurement made in the outside of the dwelling.

The complete questionnaire contained common demographic questions, noise perception questions, noise nuisance questions, noise effects questions, cultural opinions about noise effects, residential environment opinions, and some questions used to economically valuate the unsatisfied need of silence. Only some of these questions are used in the results of this work.

The set of questions about "loudness perception" of sound sources and "degree of annoyance" was asked in different ways and categories answers, inserted among other questions. As the principal noise source in this city is traffic noise (that means that the Leq(A) measured value depends principally of this noise energy), we have selected for this survey the questions that have relation to this source. The questions considered with the corresponding answer categories and prevalence is shown on tables 2 to 6 (translation from Spanish has been made with great zeal).

Statistical Techniques.

The chi-square test was used to detect association or independence. Kendall's Tau-b and Tau-c was used in the correlation analysis.

The mathematical technique of main components was used in factorial analysis. Bartlett's Test of Sphericity and Kaiser-Meyer-Olkin measure of sampling adequacy test was used to indicate if the factor model was appropriate. The Varimax procedure was used to rotate de matrix.

RESULTS AND DISCUSSION.

Measurements.

As a global result of the measurements, the mode, average, standard deviation, minimum and maximum for each period of the measurements of Leq(A) made in the 115 points of the city, are shown on table 1.

Table 1. Mode, average, standard deviation, minimum and maximum for each period of the measurements of the Leq(A) made in the 115 points of the city.

Variable	*Period*	*Mode*	*Average*	*S. Deviation*	*Minimum*	*Maximum*
Leq(A)	1	71	68	7	45	77
	2	74	68	7	47	85
	3	71	68	6	50	78
	4	73	69	6	48	78
	5	59	64	7	44	76
	6	59	58	8	38	75
	7	60	59	8	32	74

The centre of the town is a common point of the city, where people of all ages very often go since there they are the post office, banks, municipality, court, shops, etc, all around a 100 x 200 m plaza. This place has a constant one minute Leq(A) of 70 dB ± 2 dB from 07:00 hrs. to 22:00 hrs. Then, the Leq(A) diminishes at a rate of 2.5 dB per hour reaching the level of 50 dB at 05:00 hrs. This place is catalogued by 13.3% of those interviewed as "very noisy", 48.4% as "noisy", 36.2% as "not very noisy" and 2.1% did not know or did not answer.

Demographic Prevalence.

The demographic prevalence of the survey is in concordance with the demographic statistics index of city. For example, the age variable has a triangular distribution with a relatively equal participation of men and women in every range of age. The prevalence of unemployment and socioeconomic groups are also in accordance with the official statistics index. These results reinforce the presumption of a good setup of the survey.

Community Response.

The prevalence for each category of the set of questions considered is shown on tables 2 to 6. In these tables the difference with 100% in every row corresponds to percentage of people who did not know what to answer or did not answer.

Table 2. Prevalence's of questions A and B.

Questions	Categories			
How do you consider the actual environmental conditions of your dwelling?	Very acceptable	Acceptable	Bad	Very bad
A. Day silence outside house	4.9%	21.4%	42.5%	20.1%
B. Night silence outside house	9.3%	24.9%	35.9%	19.0%

Table 3. Prevalence's of question C.

Variables	Categories			
How do you consider the actual environmental conditions of your dwelling?	Very low	Low	High	Very High
C. Amount of road traffic	5.1%	30.9%	31.9%	18.6%

Table 4. Prevalence's of questions D and E.

Variables	Categories				
When you are outside your dwelling, how loud do you hear the following noise sources?	Very quiet or not heard	Quiet	Moderately loud	Loud	Very loud
D. Traffic noise outside house.	1.5%	4.7%	25.2%	33.4%	28.1%
E. Vehicle horns outside house.	5.5%	14.0%	31.7%	22.4%	16.5%

Table 5. Prevalence's of questions F to M.

Variables	Categories			
What is the degree of annoyance that the following noise sources causes you?	Slightly or no annoyance	Moderately annoyed	Annoyed	Very (Highly) annoyed
F. Vehicle acceleration noise.	10.1%	16.7%	33.8%	29.8%
G. Break noise.	10.1%	22.6%	34.5%	21.8%
H. Vehicles without or bad exhaust mufflers.	7.8%	14,8%	27.5%	37.0%
I. Vehicles horns.	4.9%	13.3%	34.2%	37.8%
J. Car traffic.	21.8%	38.3%	23.3%	6.1%
K. Truck traffic.	8.9%	19.9%	35.7%	24.3%
L. Motorcycle traffic.	15.4%	23.0%	31.9%	18.6%
M. Bus traffic.	16.3%	25.4%	33.4%	14.0%

Table 6. Prevalence's of question N to P.

Variables	Categories		
When you are in the outside of your dwelling, how loud do you hear the environmental noise?	Quiet	Moderately loud	Very loud
N. During daytime	14.2%	50.3%	33.0%
O. During week nighttimes	33.4%	46.1%	17.3%
P. During weekend nighttimes	17.8%	46.7%	33.0%

Vehicles horns and vehicles without or bad exhaust mufflers are perceived as the most annoying noise sources of traffic noise. The type of traffic that makes the most annoying noise are the trucks followed by motorcycles.

Daytime noise is perceived louder than nighttime's noise and weekend nighttimes is perceived louder than week nighttimes. A 43.8% of the interviewed said that sleeping was interrupted by noise.

We found association and correlation between the qualification of noise loudness at the outside of the dwellings at nighttime and daytime, and perception of the amount of traffic, with respect to the noise index LeqN, LeqD, and LeqDN. The results obtained are shown on tables 7 and 8.

As it can be seen in table 7, there is a better association between the qualification of amount of traffic to index LeqDN than the qualification of noise loudness at daytime and nigh time with respect to noise index LeqD and LeqN. Nevertheless, the qualification of the environmental noise is in concordance with the loudness of noise perceived and with noise index. Also, as is

seen in table 8, there is a correlation between the perception of amount of traffic to index LeqDN and noise loudness at daytime and nigh time with noise index LeqD and LeqN.

Table 7.

Association between	Degree of freedom	Chi square	Sig. level
Perception of night noise – LeqN	12	33.04	< 0,1%
Perception of day noise – LeqD	12	53.70	< 0,1%
Perception of amount of traffic – LeqDN	12	58.71	< 0,1%

Table 8.

Correlation between	Tau_b	Tau_c	Sig. level
Perception of night silence – LeqN	0,162	0,152	< 0,1%
Perception of day silence – LeqD	0,270	0,241	< 0,1%
Perception of amount of traffic – LeqDN	0,268	0,252	< 0,1%

In the factor analysis made on all the variables of table 2 to table 6, including LeqDN, the following results were obtain:

The value of the determinant of the correlation matrix is 0.001815, which applied to the Bartlett's Test of Sphericity, a Chi-Square of approximately 2465 is obtained, with 136 degrees of freedom and a significance level of less than 0.0%. The Kaiser-Meyer-Olkin measure of sampling adequacy gave 0.878. These values indicate us that the factorial analysis is applicable. Three components have been extracted. The total variance explained by each component is 23.5%, 16.0% and 14.4% with a cumulative total of 53.9%. Table 9 shows the rotated factorial matrix with the three extracted components.

Table 9. Rotated matrix of the factors.

Variables		Component		
		1	2	3
Actual conditions?	A. Day silence outside house	0,71	0,11	0,18
	B. Night silence outside house	0,75	-0,04	0,16
	C. Amount of road traffic	0,53	0,17	0,03
How loud?	D. Road traffic outside house.	0,66	0,28	0,21
	E. Car horns outside house.	0,57	0,20	0,21
Annoyance caused by the following noise sources?	F. Car acceleration noise	0,18	0,19	0,76
	G. Break noise	0,17	0,21	0,80
	H. Vehicles without or bad exhaust mufflers	0,04	0,07	0,80
	I. Car horns	0,05	0,42	0,56
	J. Car traffic.	0,24	0,77	0,10
	K. Truck traffic.	0,25	0,73	0,13
	L. Motorcycle	0,09	0,64	0,24
	M. Bus traffic	0,05	0,81	0,18
Environmental noise outside the dwelling.	N. Noise during daytime	0,64	0,30	0,03
	O. Noise during week nighttimes	0,71	0,15	0,04
	P. Noise during weekend nighttimes	0,70	0,05	0,07
Measurement.	Q. LeqDN	0,55	-0,01	-0,05

A factorial weight indicates us the degree of correlation between the variables and the component obtained.

The first component can be related to the subjective long time (one or more years) impression of the environmental noisiness in the neighbourhood. The long term environmental noise is

much more than the subjective impression of traffic noise; it includes other annoying noise sources like children playing in the street, dog's barking, neighbour's radio or TV, parties, and other occasionally noisy activities which may have (or may not have) a lower acoustic energy than traffic noise. As transportation noise is the main contributor to the measured LeqDN, this can explain the weaker correlation of all traffic noise sources and LeqDN to this component.

The second component can be related to the dose of the daily experience of annoyance due not only to the generic noise sources but also to the bias produced by the annoying of traffic jam. These annoyances have been psychologically grouped in these generalized noise sources.

The third component can be related to the annoyance produced by specific and identifiable noise sources of road transportation, which are characterized for their considerable acoustic energy.

CONCLUSIONS.

With respect to noise measurements, Valdivia is a city that, as many others of this size in Chile [5], has noise pollution due to the great number of vehicles that circulate on its narrow avenues and streets.

We can say that most of the people are aware of the different noise levels on the city, as there is a correlation between the measured LeqD and LeqN and the perceived loudness in the different neighbourhoods. Nevertheless, the explanation for not a stronger correlation could be that the perception of noisiness includes other noise sources of lower energy than traffic noise, who are heard but are not interpreted by the measured Leq. This could also explain the stronger correlation between the perception of amount of traffic and the measured LeqDN.

In the factorial analysis, the total variance explained by the three extracted components is 53.9%. The first component is related to the subjective long time impression of the total environmental noisiness of the neighbourhood; the second component is related to the dose of daily experience of annoyance of noise sources define by wide concepts such a "traffic"; the third component is related to identifiable noise sources of road transportation which have a considerable acoustic energy.

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