NOISE STUDY OF SALAMANCA (SPAIN) BY MEANS OF A CATEGORIZATION METHOD

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ABSTRACT

In the last years, different studies have been carried out by our investigation group in different medium-sized Spanish cities (Cáceres, Badajoz, Vitoria-Gasteiz). In the present work a noise study of the city of Salamanca is presented. As in the previous studied cities, Salamanca was categorized according to their roadway characteristics. Thus, the streets of the city were distributed in six different categories, one of them including walking streets.

The study is based in 15 minutes samples taken in diurnal period and in some weekly measurements. In working hours, the levels measured surpass considerably in almost all the samples the 55 dBA value. Histograms, relationships among statistical levels of exceedance (Lx) and energy-averaged sound levels (Leq) were established. In addition, regression equation of Leq as a function of the logarithm of the number of vehicles per hour are presented.

The results show a clear difference between categories, showing the utility of this kind of studies. The noise levels in several streets of the city must be considered harmful.

INTRODUCTION

The technological revolution of the two last centuries has produced a lot of advantages for the human lives, but also some disturbances. Thus, some aspects related to this revolution are of increasing interest in our society. This is the case of the study of noise as a disturbing element in our lives. To this effect, in the last decades, several studies have been carried out in different cities of the world. These studies have been focussed on some of the interest characteristics of noise, such as sources, noise pollution level, noise exposure, physiological and psychological effects, etc. which have been deal with simultaneously or on a individual basis[1, 2].

In Spain, the first works about these problems come from the sixties[3], and, nowadays, there are some studies carried out in several Spanish towns[4, 5, 6].

A noise study of the city of Salamanca is presented in the framework of the study of medium-sized Spanish cities currently carried out by our investigation group [7,8,9]. As in the previous works, the noise study was carried out by a categorization method, assuming that, among the different sources of noise, traffic can be considered as the most important source during the day. This was expected to be a reasonable hypothesis which was later confirmed by the results described below, since the focus of our study was on the inhabited part of the city, where there are no significant industries, aircraft noise, or train noise. In that way, all the streets of the cities were assigned to six different categories defined in accordance with the use in communicating the different zones of the city.

In comparison with the grid method, the categorization method allows to study the noise in the city with a reduced number of measurements. With an adequate selection of sampling points, this procedure leads to adequate results.

METHODOLOGY

Description Of The City

The city of Salamanca has 160 000 inhabitants, although this number increases during the period from September to July due to the arrival of a relevant number of university students. Besides, during all the year, an important amount of tourists visits the city.

The city is located at 800 m over the see level, occupying 40 km^2, approximately. It has a clearly distinguished old part and a modern area that can be divided in several parts, as it can be seen in figure 1.

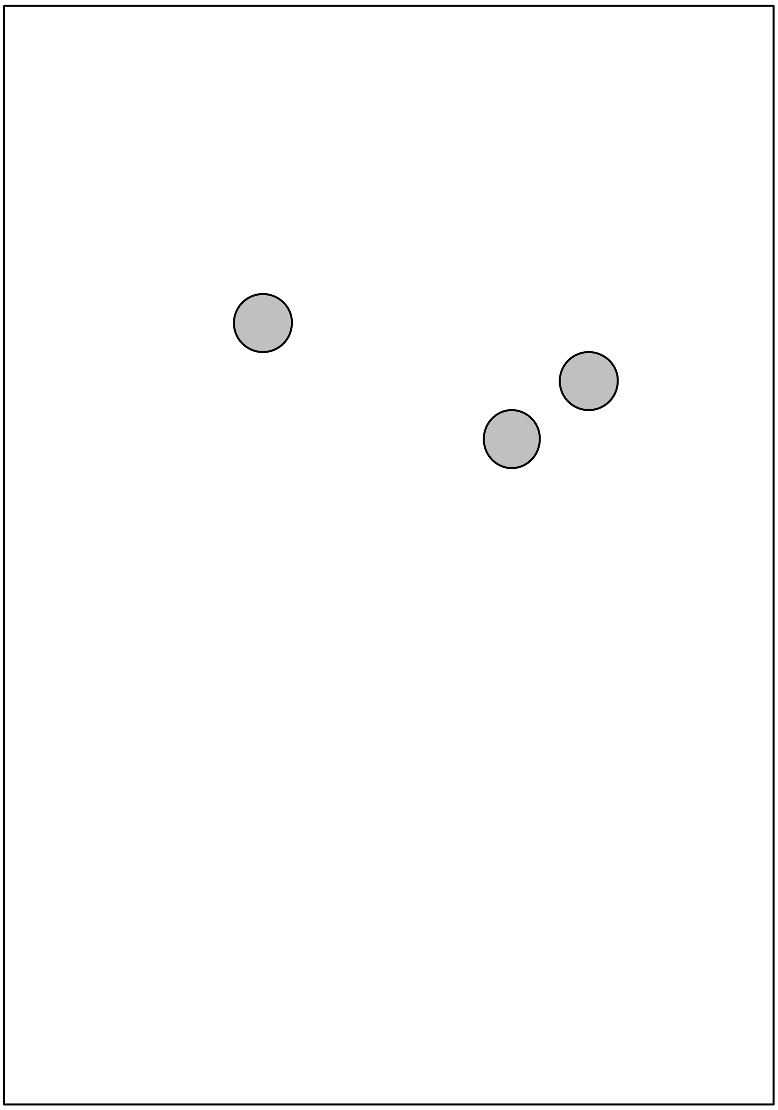
Categorization

As mentioned, the city was categorized according to their roadway characteristics. The categorization used is an improvement of the categorization used in previous studies carried out by our investigation group[10]. The following six categories were established:

Type 1 includes those preferential streets whose function is to connect the city with other Spanish cities (national roads for the cities studied) and to connect these streets among them (in general, in the last case, the streets are indicated by means of traffic signals).

Type 2 includes those streets that provide access to the major distribution nodes of the city. For the purpose of this study, a distribution node is considered to exist provided that at least four relevant streets meets. This definition that not cover any eventual nodes of preferential streets as defined in *Type 1* above. Besides, this category also includes the streets normally used as an alternative to the previously defined ones, in case of traffic saturation.

In the studied city, the three nodes considered are represented in figure by means of a circle.



Type 3 includes the streets that lead to regional roads, those streets that provides access from the streets include in the previous types to centres of interest of the cities (hospitals, malls, etc.) and those streets that allows a clear communication among the previous types of streets.

Type 4 includes those streets that allow a clear communication among the previously defined types of streets. Besides, this category covers the principal streets of the different districts of the city that were not included in the previously defined categories.

Type 5 includes the rest of the streets of the city except walking streets.

Finally *Type 6* category includes all the walking streets.

Sampling Point Selection

For this study, each street was measured and its length was used to calculate the entire category length. Then a pseudo-random sequence allows to choose the different points for each category. Ten different sampling points were selected for each category. Two points were considered equivalent provided that they were located on the same section of the street with no intersection between them. In this case, one of them was rejected and a new selection was made.

The proposed sampling point selection avoids the negative effect of other methods as the arbitrary selection of sampling points. Some authors have pointed out that mentioned method may lead to the noisier points being chosen, thereby introducing a bias into the results[11].

Sampling Procedure

In each selected points four measurements were done in the period from 8:00 a.m. to 8:00 p.m. (working hours). The four measurements included different days (only working days were studied), and different hour intervals. The chosen time intervals were obtained by using weekly measurements taken in each defined category, as previously described[10].

Measurements lasted 15 minutes. All the measurements were made following the ISO 1996 guidelines[12] using a 2236 B&K type I sound-level meter, with tripod and windshield. Calibration was performed using a 4231 B&K calibrator. The volume of traffic was measured and classified (cars, heavy vehicles and motorcycles) manually during the sampling; other relevant information (noise sources, meteorological conditions, street dimensions, etc.) was also taken. In each measurement L_{eq}, L_{10}, L_{50}, L_{90}, L_{max} and L_{min}, in dBA, were measured and written down.

RESULTS

Global Results

A total of 277 samples were taken in the city of Salamanca , being 43 the minimum number of samples taken in a category. In figure 2, a histogram of all the results obtained is presented.

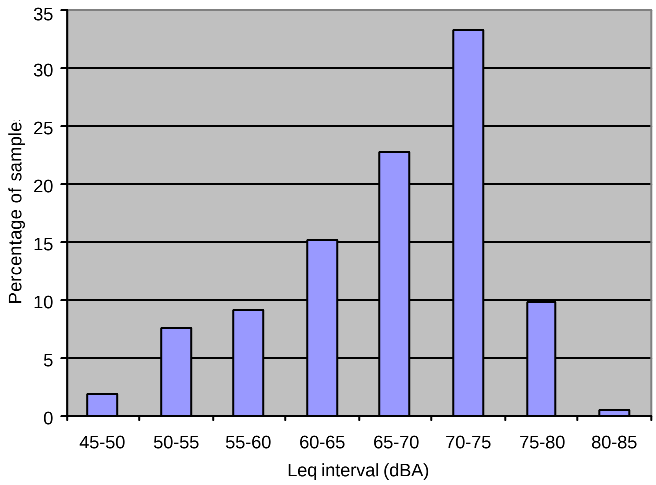


Figure 2.- Measured level histogram obtained

It is important to mention that only a percentage lower than 34 % of the measurements made in Salamanca presents values below 65 dBA. This level can be considered as the acceptable level for diurnal exposure[13]. Taking into consideration the more conservative value of 55 dBA given by the WHO for serious annoyance in daytime[14], less than the 10% of the measurement taken are under this level.

Category Results

In order to control the validity of the categorization used, a special study of the different results obtained for each category was carried out. Firstly, in table 1, the average value of equivalent level, for each category, is presented. In figure 2, the results obtained for each category are shown as histograms.

Category	Average Leq (dBA)	Category	Average Leq (dBA)
Type 1	74,2 ± 0,8	Type 4	68,9 ± 1,0
Type 2	72,1 ± 1,0	Type 5	61,6 ± 1,2
Type 3	70,8 ± 0,8	Type 6	58,1 ± 1,3

Table 1. Values of average equivalent level for each category in Salamanca.

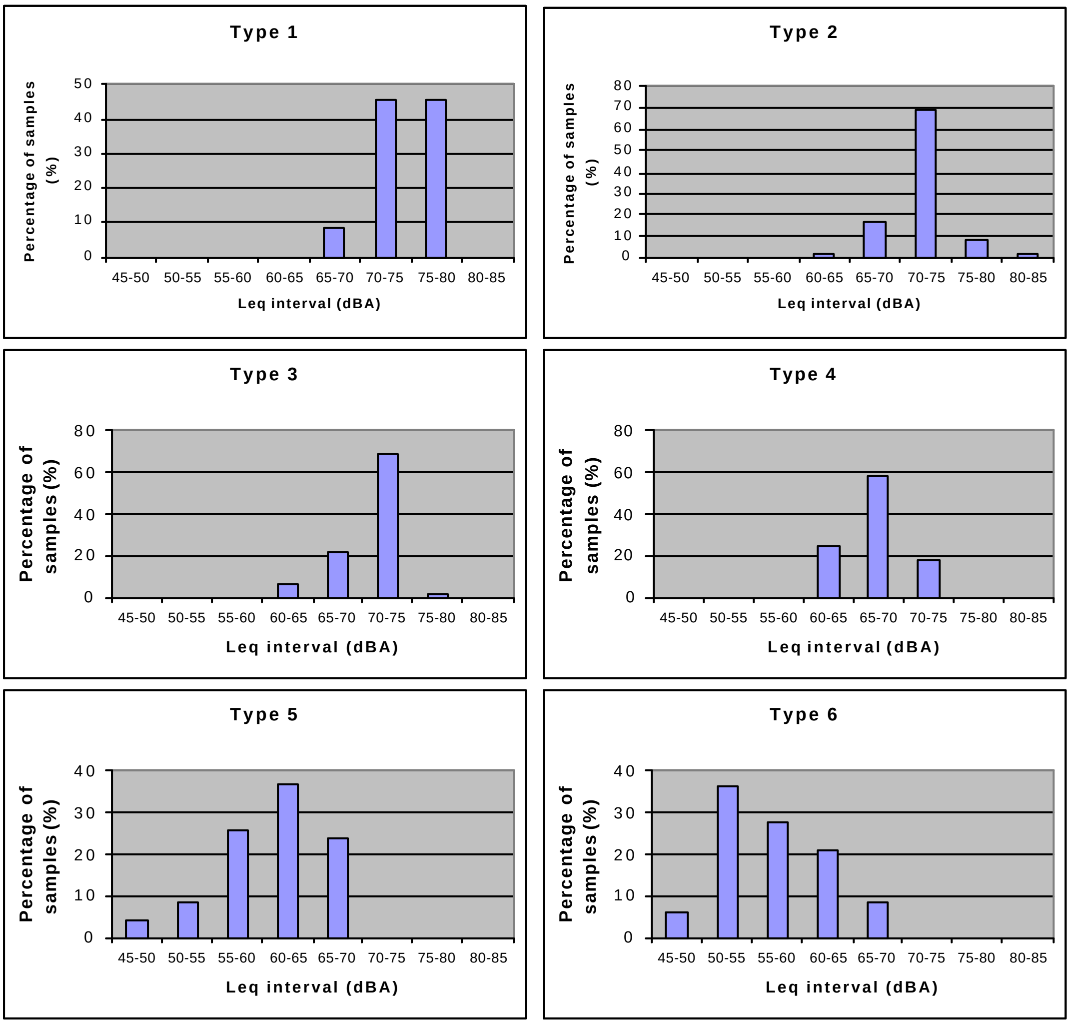


Figure 2.- Measured levels histograms obtained for each category.

Both, the histograms and the average equivalent level obtained, seem to show that there is a clear difference among the different average Leq values obtained. Nevertheless, a more detailed study would be convenient.

<u>Relationship Among Measured Levels</u>

In order to compare the different levels a study of relationships among the different statistical levels of exceedance (Lx) and the energy-average sound level (L_{eq}) measured follows:

$L_x = a \cdot L_{eq} + b$	$L_{10}= f(L_{eq})$	$L_{50}= f(L_{eq})$	$L_{90}= f(L_{eq})$
Slope (a)	1,08	0,96	0,70
Origin (b)	-2,73	-3,55	7,51
Coefficient of determination (r^2)	0,96	0,83	0,61

Table 2. Linear relationship among the statistical levels of exceedance (L_x) and the energy-average sound level (L_{eq}).

According to the results contained in *Table 2* above, L_{eq} explains almost all variability in L_{10}. In the case of L_{90}, there is an important part of variability not explained by L_{eq}. These results are similar to those obtained in previous works[7, 8].

Relationship Between Number Of Vehicles And Noise Level

As mentioned previously, the present study is based in traffic noise as the principal noise source in the city. In order to confirm this assumption the relationship between the amount of vehicles and the measured noise level was studied. The result is the following:

$$\text{Salamanca: } L_{eq} = 8.0 \text{ Log } Q + 48.5; \; r^2 = 0{,}76$$

As can been seen, the logarithm of the vehicles flow is a good explanation of the Leq variability. This leads to confirm the assumption made. The relationship observed results obtained for the city of Salamanca are in good concordance with others obtained by other authors summarized in previous works[8].

CONCLUSIONS

a) From the statistics of the measurements of noise levels in the city studied, categorizing of the city according to its roadway characteristics seems to be an useful and an adequate method to study the noise in a city.
b) A great percentage of energy-averaged sound levels (L_{eq}) were over 55 dBA. With the limitations of this study, traffic noise must be considered as an important contaminant agent.
c) A strong correlation was found for L_{10} and L_{eq} levels. L_{eq} is a good measure of L_{10} variability. L_{90} variability is not so clearly explained by L_{eq}.
d) The behaviour of energy-averaged sound level as a function of logarithm of vehicle flow rate is similar to other studies.

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