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DESCRIPTIVE ANALYSIS OF THE TEMPORARY EVOLUTION OF THE URBAN NOISE

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ABSTRACT
The following paper develops an analysis of the daily evolution of noise in a specific street in Valladolid, (SPAIN), a medium size city with about 350.000 people. The data have been taken every thirty minutes continuously, beginning on a Friday at 14: 00 and finishing seventeen days later, Monday, at the same hour. This yields a total amount of 818 sets of data. Each of these sets includes five acoustical magnitudes (L_{eq}, L_{10}, L_{50}, L_{90}) and the standard deviation of (σ). Three different time periods will be analysed: day time (8: 00 to 20: 00), evening time (20: 00 to 23: 00) and night time (23: 00 to 8: 00). The descriptive analysis shows that the behaviour of the acoustical magnitudes is similar between them and different to the behaviour of σ. When the urban noise is small, then σ is high, and when the urban noise is high then σ is small. This behaviour is found in every subset of data analysed. It can also be seen, that the acoustical variables (L_{eq}, L_{10}, L_{50}, L_{90}) present the same patterns on Monday-Friday weekdays, but Saturday and Sunday patterns are different from regular weekdays and from one another. Concerning the statistical variable σ, Monday through Thursday (M-Th) weekdays have a similar behaviour, but Friday, Saturday and Sunday have a specific and different behaviour, both between them and compared to M-Th behavior. If the three different periods of the day are compared, it can be seen that they are all different from one another. Once the descriptive analysis has been made, we have used the Kolmogorov-Smirnov statistic to contrast if the days of the week are similar and if the periods are similar. It has been obtained that they are not and that the behaviour of all magnitudes responds to what was obtained with the descriptive analysis.

1 - INTRODUCTION

In this paper we develop a statistical descriptive analysis of a set of data in order to study the daily evolution of urban noise in a specific street in Valladolid (SPAIN), a medium size city with about 350.000 people.

The equipment we have used is B&K 4427. The data have been taken every thirty minutes continuously, beginning on a Friday at 14:00 and finishing seventeen days later, Monday, at the same hour. This yields a total amount of 818 observations. Each of these observations includes all six magnitudes (L_{eq}, L_{10}, L_{50}, L_{90}, $\bar{L}$ and σ, the standard deviation of $\bar{L}$).

In our analysis we distinguish three different time periods in one day: day time from 8:00 to 20:00, evening time from 20:30 to 23:00 and night time from 23:30 to 7:30. We thus have 427 observations corresponding to day time, 102 observations corresponding to evening time and 289 observations for night time.

The data are also analysed according to the day of the week. The 818 observations can be grouped in 7 data sets with different amount of observations. Saturday and Sunday have 144 observations, that is three days, Monday has 126 observations, Tuesday, Wednesday and Thursday have 96 observations and Friday has 116 observations.

2 - DESCRIPTIVE ANALYSIS

We have used the statistical package Statistica, release 5.5 to process our data.
Figures 1 and 2 represent the mean values of the variables by week-day and by day time periods. We have separated the variable sigma from the others because it has a different scale. These graphs, also show the different behaviour of the mean value of the variable sigma compared with the mean values of the other variables. During day and evening time, the mean value of sigma is maximum on Sundays whereas it is minimum on Sundays for the other variables. In the night time the mean value of sigma are the highest, and the mean values of the other variables are the lowest.

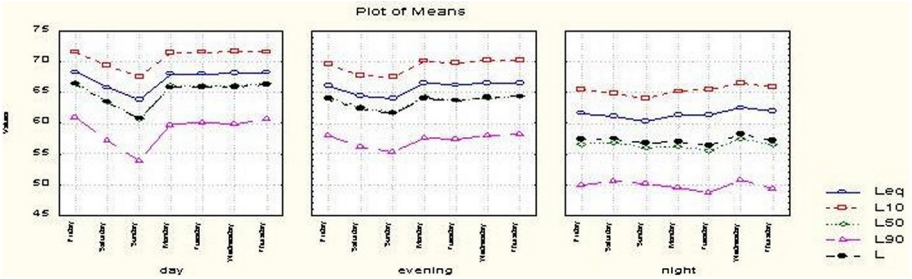

Figure 1: Mean value of the variables according to day of week.

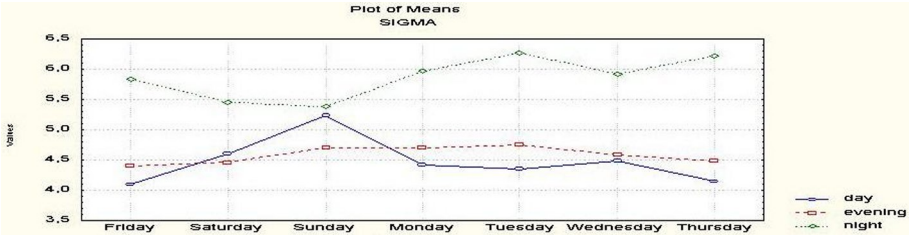

Figure 2: Mean value of the variables according to day period.

From figure 1 it can also be observed that the behaviour of the mean values of L_{eq}, L_{10}, L_{50}, L_{90}, $\bar{L}$ is very similar. Since this fact has been detected all along the study, from now on we will refer only to the variable L_{eq}. It is interesting to have a closer look at the correlation matrix of the variables, shown in Table 1. In this table it is shown that all variables are highly correlated. Sigma is negatively correlated with the others, whereas the correlation is positive between the rest of variables, so we can say that if L_{eq} is high, sigma will be small and viceversa. Table 2 and table 3 represent some statistical measures of the variables L_{eq} and sigma according to the day of the week and to the periods of the day.

Variable	Sigma (σ)	L_{eq}	L_{90}	L_{10}	L_{50}	$\bar{L}$
Sigma (σ)	1,000000	-,777771	-,915275	-,727222	-,856642	-,860097
L_{eq}	-,777771	1,000000	,962970	,992430	,979504	,985566
L_{90}	-,915275	,962970	1,000000	,939620	,985640	,990869
L_{10}	-,727222	,992430	,939620	1,000000	,966695	,972372
L_{50}	-,856642	,979504	,985640	,966695	1,000000	,997624
$\bar{L}$	-,860097	,985566	,990869	,972372	,997624	1,000000

Table 1: Correlation matrix.

Variable	N	Average	Sta. Dev.	Median	Minimum	Maximum
L_{eq}	818	64.83667	3.278318	65.30000	57.10000	71.20000
L_{eq} Friday	116	65.94569	3.283725	67.20000	58.60000	71.20000
L_{eq} Saturday	144	64.01042	2.543516	64.70000	57.60000	67.50000
L_{eq} Sunday	144	62.64931	2.368913	63.30000	57.90000	66.40000
L_{eq} Monday	126	65.20000	3.610451	67.20000	57.10000	69.90000
L_{eq} Tuesday	96	65.42396	3.474440	67.30000	57.30000	69.3000
L_{eq} Wednesday	96	65.98125	2.896797	67.30000	58.60000	69.90000
L_{eq} Thursday	96	65.80833	3.314138	67.50000	57.90000	69.50000
L_{eq} Day	427	67.00328	1.970019	67.70000	58.80000	71.20000
L_{eq} Evening	102	65.60784	1.326403	65.50000	63.00000	67.90000
L_{eq} Night	289	61.36332	2.203210	61.20000	57.10000	68.00000

Table 2: Summary statistics, variable L_{eq}.

Variable	N	Average	Standard dev.	Median	Minimum	Maximum
SIGMA	818	4.98411	.902976	4.80000	3.10000	7.60000
σ Friday	116	4.67241	.969768	4.40000	3.10000	7.60000
σ Saturday	144	4.88750	.665207	4.70000	3.90000	7.20000
σ Sundays	144	5.22083	.646332	5.20000	3.10000	6.80000
σ Monday	126	5.06429	.952173	4.80000	3.40000	7.00000
σ Tuesday	96	5.08333	1.012934	4.6000	3.40000	7.40000
σ Wednesday	96	5.00313	.891534	4.70000	3.50000	7.30000
σ Thursday	96	4.92708	1.151153	4.6000	3.10000	7.40000
σ Day	427	4.51663	.652751	4.40000	3.10000	6.70000
σ Evening	102	4.57451	.307557	4.50000	3.90000	5.30000
σ Night	289	5.81938	.752384	5.80000	4.10000	7.60000

Table 3: Summary statistics, variable sigma.

From the table 1, table 2 and table 3 and from figures 1 and 2 it can be deduced that the mean value of the noise level takes its lowest value on Sundays. On the other hand, the variable sigma has its maximum on Sundays during the day time period, remains approximately constant during evening time and takes its lowest values on Sunday's night period. Figures 3 and 4 represent L_{eq} and sigma mean values for the different time periods, and the contrast between both variables appears evident. At day time, the noise level is high but does not vary very much, while at night time, the mean noise level is low, but varies so much that at some specific moments it can reach rather high values. As it can be seen in table 2, the difference between the L_{eq} maximum and mean value is 4.19672 for the day time and 6.63668 for night time.

Figures 5a to 5d correspond to Box-plots that represent the variation of the noise level, L_{eq}, and the variability, sigma, in the subsets of data analysed. In these figures we can see the behaviour of the variables depending on the week day and on the period of the day. Generally, the variables L_{eq} and sigma turn out to be asymmetric, the former on the left (low levels of noise), the later on the right (high values of sigma). The noise level on Saturdays and on Sundays is lower and more homogeneous (the central box is small), while on Fridays the urban noise is the highest. It can also be seen for L_{eq}, that for all days the distance from the median to the minimum is higher than the distance from the maximum to the median. This means that the data are more dispersed in the low range levels of noise than in the high levels. This dispersion is bigger on week-days (Monday to Friday) than on weekends. The variable sigma presents more dispersion above the median. The variable L_{eq} presents heavy tails on the left and the variable sigma on the right. These tails are heavier on week-days.

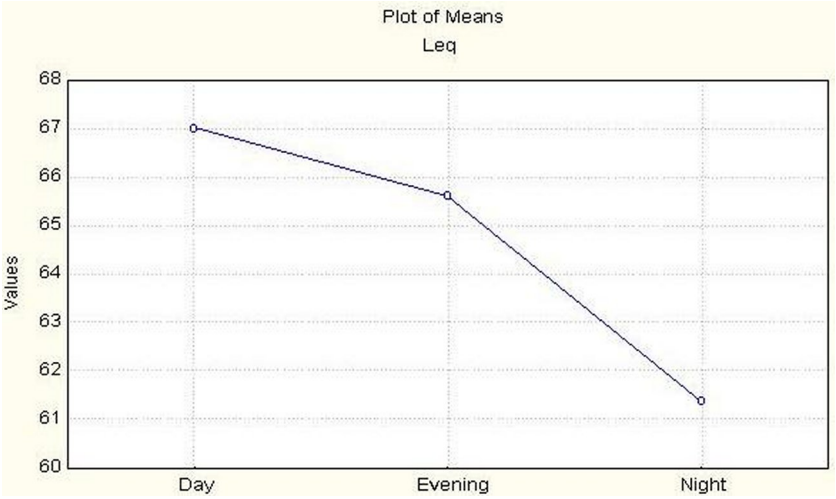

Figure 3: Plot of means.

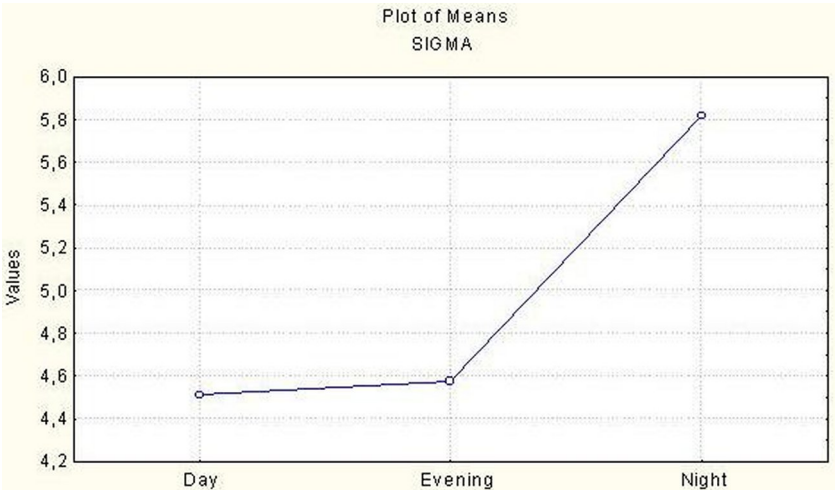

Figure 4: Plot of means.

From the descriptive analysis we can conclude that week days are different from weekends.
If we look at the time of the day, we observe that during the day time period, the noise is higher and more dispersed below the median. In the evening time period the variable L_{eq} is regular and for the night time the dispersion is bigger above the median. We can also see that the variable sigma behaves just in the opposite way. That is, sigma has its highest values for the night time period.
From the Box-plot according to week day and day time, which is not shown in this paper, it can be seen that for the day time period, Monday to Friday weekdays show a uniform pattern while Saturdays and Sundays are similar only between them. For the evening time, Sundays are different and present heavy tails on the right. If we look at the night period, we can observe that Saturday and Sunday are very regular and that weekdays show some dispersion to the right. The sigma variable, as expected, behaves on the contrary.

3 - COMPARISONS OF THE MEAN VALUES

According to the descriptive study, it can be deduced that the noise level is different on weekdays than on weekends. In order to verify this conclusion we have made a hypothesis test by using the Kolmogorov-Smirnov Statistics. We intend to test, for example, if the noise level measured on Mondays is similar to the noise level measured on Tuesday as it is inferred from the descriptive analysis, or if, on the contrary, measurements are different. The results are shown in table 4. When the result obtained from the hypothesis test is non significant (n. s.) we will assume that the hypothesis relative to equal mean values in those days is correct. If the result form the hypothesis test is below a certain critic value ($p < 0.01$) it means that the difference between the mean values is rather significant and that we can reject

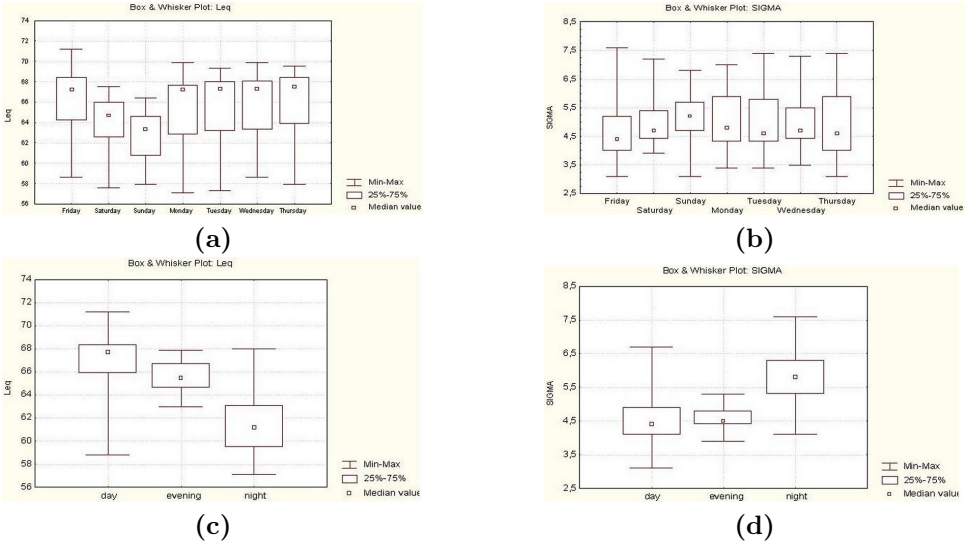

Figure 5: Box plots for L_{eq} and σ.

the "equal mean values" hypothesis. If the error we make rejecting the hypothesis is below 5%, it is expressed in the table with *. If the error is below 1%, the table shows **. Finally, if the results obtained from the hypothesis test are very significant ($p < 0.001$) the hypothesis can be rejected with an error below 0.1 % and we will show *** in table 4.

	Friday		*Saturday*		*Sunday*		*Monday*		*Tuesday*		*Wednesday*		*Thursday*	
	L_{eq}	σ	L_{eq}	σ	L_{eq}	σ	L_{eq}	σ	L_{eq}	σ	L_{eq}	σ	L_{eq}	σ
Friday	-	-	***	***	***	***	n. s.	**	n. s.	*	n. s.	***	n. s.	n. s.
Saturday	***	***	-	-	***	***	***	*	***	*	***	n. s.	***	**
Sunday	***	***	***	***	-	-	***	***	***	***	***	***	***	***
Monday	n. s.	**	***	*	***	***	-	-	n. s.	n. s.	n. s.	n. s.	**	n. s.
Tuesday	n. s.	*	***	*	***	***	n. s.	n. s.	-	-	n. s.	n. s.	n. s.	n. s.
Wednesday	n. s.	***	***	n. s.	***	***	n. s.	n. s.	n. s.	n. s.	-	-	n. s.	*
Thursday	n. s.	n. s.	***	**	***	***	**	n. s.	n. s.	n. s.	n. s.	*	-	-

Table 4: Results of the hypothesis test, mean values equal for L_{eq} and σ.

4 - CONCLUSIONS

The descriptive analysis shows that the behaviour of the acoustical magnitudes are L_{eq}, L_{10}, L_{50}, L_{90} and $\bar{L}$ is similar between them. The variable σ, as a measure of the variability noise level, behaves opposite to the other variables. When the level of urban noise is small, then its variability is high, and when the urban noise is high then s is small.

On week days, Monday-Friday, urban noise presents the same patterns, but on Saturday and Sunday the patterns are different from regular weekdays and from one another. So we can consider three set of data: weekdays, Saturdays and Sundays.

For the variable σ, we can divide the data set in 4 data set, Monday through Thursday (M-Th), Friday, Saturday and Sunday. That is, weekdays have a similar behaviour, but Friday, Saturday and Sunday have a specific and different behaviour.

The three different periods of the day are all different from one another.

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