Can weekly noise levels of urban road traffic, as predominant noise source, estimate annual ones?

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The effects of noise pollution on human quality of life and health were recognised by the World Health Organisation a long time ago. There is a crucial dilemma for the study of urban noise when one is looking for proven methodologies that can allow, on the one hand, an increase in the quality of predictions, and on the other hand, saving resources in the spatial and temporal sampling. The temporal structure of urban noise is studied in this work from a different point of view. This methodology, based on Fourier analysis, is applied to several measurements of urban noise, mainly from road traffic and one-week long, carried out in two cities located on different continents and with different sociological life styles (Cáceres, Spain and Talca, Chile). Its capacity to predict annual noise levels from weekly measurements is studied. The relation between this methodology and the categorisation method is also analysed.

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I. INTRODUCTION AND BACKGROUND

One of the major health problems in developed cities worldwide is noise pollution. Hence, its regulation has been one of the main concerns of city managers. To carry out this regulation, it is necessary to have thorough knowledge of the characteristics of urban noise sources and its effects. To do this, a broad knowledge of both its spatial distribution and its temporal variability is needed.[1–4] This spatial and temporal variability has been studied under different approaches in the literature.[5–13]

Traditionally, studies on the impact of urban noise on the population have been based on the grid method when making a spatial sampling of the noise distribution.[14–17] Given the problems associated with this method, other alternatives for planning the noise spatial sampling have been proposed, such as the method of categorisation, which is based on the concept of street functionality.[18] The results displayed by the categorisation method have shown a significant stratification of urban noise in several categories,[3,19] also being applicable to cities of very different sizes,[20,21] and with a predictive capability of the expected noise levels above 90%,[22,23] which are better results than those found with the grid method.[24]

Planning the sampling points, their distribution throughout the day, week, or year and the duration of the measure is essential in any study of the impact of urban noise on populations. Although the spatial sampling has been widely studied, as indicated, the same has not happened with the temporal sampling where the predominant analysis is the statistical one.[5,25–33] However, the predictive models concerning the distribution of noise require that proper temporal distribution of the spatial variability of traffic flow be proportionated in order to run correctly.[11,21,34] In this regard, various studies have analyzed the effect of a random sampling on measurement periods of one year or comparable.[13,26,35] It is found that the selection of random days in a year time can allow estimation of average annual sound values with lower uncertainties that if sampling is performed on consecutive days. Further, it has been shown that working with urban road stratification for estimating the traffic flow significantly improves noise predictions.[12,36]

In this sense, a new approach to the space-time structure of urban noise from discrete Fourier analysis has already been made.[37] Following this methodology, a database of weekly noise measurements was analysed to search the continuous and main harmonic components using the fast Fourier transform (FFT).[38] Subsequently, the predictive ability of these weekly components of long-term parameters was studied. In addition, the relation between this methodology and the categorisation method was analysed.

The cities in which the measurement sampling was conducted as well as the sampling method used are presented in Sec. II. In Sec. III, the results are shown followed by a discussion of the results. The main conclusions are summarised in Sec. IV.

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II. METHODS

A. Cities studied

The present work was carried out in the city of Cáceres (Spain, Europe) and in Talca (Chile, South America) as a check city. Cáceres is the second largest town in Extremadura (a region in southwestern Spain) with an area of 12.7 km.[2] It has a population of approximately 96 000 inhabitants according to the Spanish Statistical National Institute (increasing to over 110 000 during the academic year due to the presence of over 10 000 students at the University of Extremadura, and on holiday due to a large number of tourists, as Cáceres is a World Heritage site). The mean annual temperature and rainfall are 16.1 °C (60.98 °F) and 523 mm, respectively. The city of Talca is located in the VII Region of Chile called Maule (in central Chile) and has a population of 200 000, with an area of 29 km.[2] As occurs in Cáceres, its population increases due to students during the academic year, as it has over nine universities. The city of Talca is crossed from north to south by the South Pan-American Highway, the main route between the cities of Chile. There have recently been improvements in the traffic flow with the creation of two ring roads in the north and south of the city. The average annual temperature is 13 °C (55.4 °F) and the mean annual rainfall, 750 mm.

B. Sampling method

As previously mentioned, the categorisation method was used in this study.[19–22] The definitions for the different categories are as follows.

Type 1 comprises those preferential streets whose function is to form a connection with other Spanish towns (national roads for the five towns studied) and to interconnect those preferential streets (in general, the indication of this latter type of street is its system of road signs).

Type 2 comprises those streets that provide access to the major distribution nodes of the town. For the purpose of this study, a distribution node is considered to exist when at least four major streets meet. This definition does not include any possible nodes of preferential streets as defined in type 1 above. This category also includes the streets normally used as an alternative to type 1 in case of traffic saturation.

Type 3 comprises the streets that lead to regional roads, streets that provide access from those of types 1 and 2 to centers of interest in the town (hospitals, shopping malls, etc.), and streets that clearly allow communication between streets of types 1 and 2.

Type 4 comprises all other streets that clearly allow communication between the three previously defined types of street, and the principal streets of the different districts of the town that were not included in the previously defined categories.

Type 5 comprises the rest of the streets of the town except pedestrian-only streets.

Once assigned the town streets to these categories, several sampling points were required for each category. For the selection of these sampling points, different balconies were chosen, taking into consideration the category of the street, the balcony access availability, their protection against vandalism, and the non-equivalence with other balconies (equivalent balconies were those located on the same section of a street with no important intersection between them). Moreover, in one of the balconies, we collected data for several years (from 2006 to 2011). Due to several problems (works on the streets, blackouts, etc.), only two years (2006 and 2010) are almost complete.

The indications of the standard ISO 1996-2 were followed in relation to the distance between the microphone and the facade and type I sound level metres (2236, 2238, 2250, and 2260 Brüel & Kjær) were used in all sound measurements in Talca and Cáceres. Of all sampling points considered, only those with duration of at least one week were used for this study. The recording of sound levels was with a resolution of at least one minute and A weighting was used.

Finally, in Cáceres, seven points in street category 1, six in category 2, three in category 3, six in category 4, and four in category 5 were used. Regarding Talca city, as a check city, three points were measured to verify the model in another city farther away from Cáceres. In Fig. 1, the locations of the sampling points used in this work for Cáceres [Fig. 1(a)] and Talca [Fig. 1(b)] are presented.

C. Methodology based on Fourier analysis (FFT)

Following the Fourier analysis, any continuous and periodic signal x(t) can be approximated by sums of a series of suitable chosen trigonometric functions with the corresponding amplitudes.[38] Thereby, according to the known algorithm for the calculation of complex Fourier series,[39] it will be able to decompose by FFT any sound signal along a time T in the following way:

$$x(t) = A_0^{i,k} + A_1^{i,k}\sin(2\pi \mathrm{f}_1 \mathrm{t} + \varphi_1) + \cdots + A_n^{i,k}\sin(2\pi f_n t + \varphi_n), \tag{1}$$

where f_1 is the fundamental frequency of the function and $\mathrm{f}_{2-\mathrm{n}}$ are the harmonic components. $\varphi_{1-\mathrm{n}}$ represents the phase of the function. Moreover, i refers to the station identification number, and k is the street category number. Because x(t) is a function of time and represents a physical signal, the Fourier transform has a standard interpretation as the frequency spectrum of the signal F(w). The numerical result of the FFT is a series of complex numbers, composed by real part or magnitude (amplitude $A_n^{i,k}$) and imaginary part or angle (phase φ_n), i.e.,

$$\mathcal{F}(x(t)) = F(w) = \Re(w) + \Im(w) = |\mathcal{F}(w)|e^{j\varphi(w)}. \tag{2}$$

Finally, the continuous component $A_0^{i,k}$ (linear average of signal) is calculated according to Eq. (3),

$$A_0^{i,k} = \sum_{j=1}^{T} \frac{1}{T} L_{jAeq,1h}^{i,k}, \tag{3}$$

where T represents the period of measure.

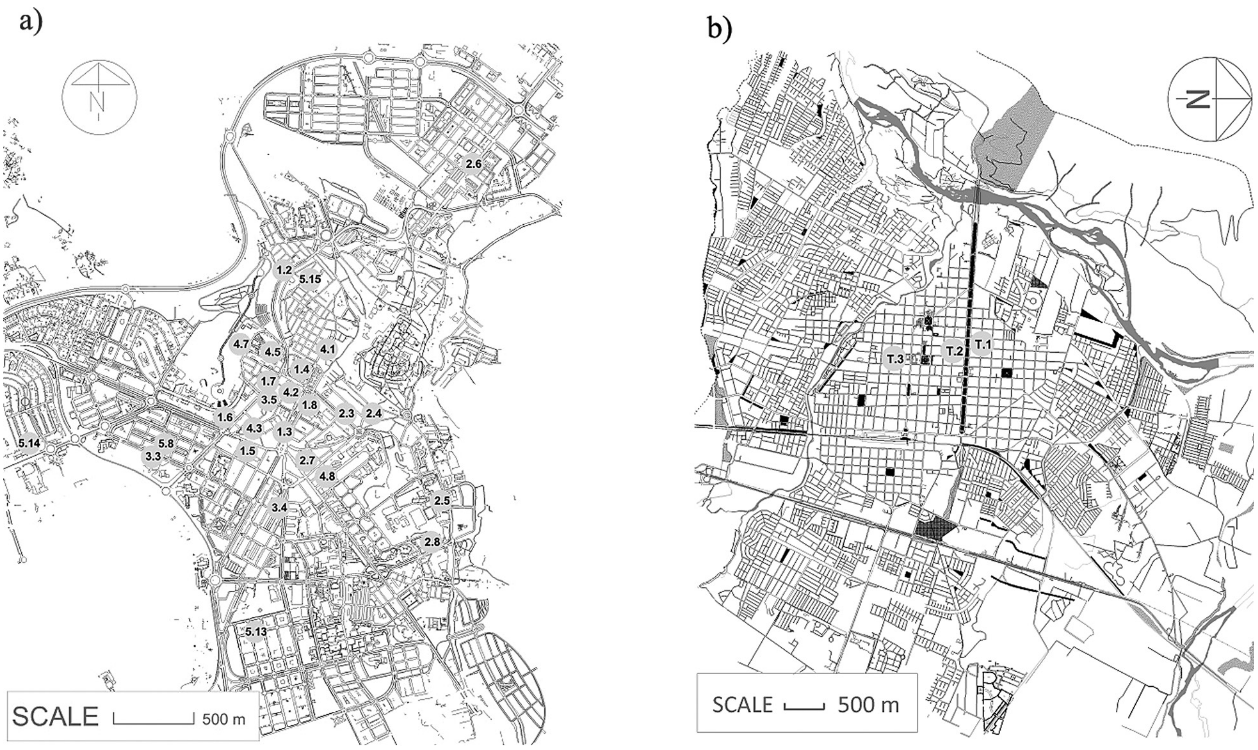

FIG. 1. Measurement stations in (a) Cáceres and (b) Talca.

III. RESULTS AND DISCUSSION

A. Analysis of the spatial stratification of the urban noise temporal structure

For each measurement station of Cáceres ($i = [1\text{–}26]$) and Talca ($i = [27\text{–}29]$) discrete Fourier analysis was made by starting all series on Monday night time at 11 p.m. according to the recommendations given in the Environmental Noise Directive.[40] Table I shows the values of the amplitudes of the harmonic components,[37] for which average values obtained in the set of analysed stations are equal or greater than 0.2 (where i refers to the station identification number, and k is the category number). The value of the continuous component (A_0) in the first row is also displayed. It is interesting to note that regardless of the variability of the continuous component in the different sampling stations, the relative and absolute importance of each component is fairly uniform.

The A_7 component (the highest one), corresponding to a 24-h period, is dominant for all measurement points. Its value never is less than 1.5 and often it reaches values greater than 2.5. The second major component is the A_{14}, corresponding to a period of 12 h. Its value is always greater than 0.9, exceeding in many cases the value of 1.2. Other components correspond to periods of 1 week (A_1), 28 h (A_6), 21 h (A_8), 8 h (A_{21}), and 6 h (A_{28}). These components are the same as those found in a previous work for annual series measured in Madrid and Málaga (Spain).[37] Figure 2 shows the FFT analysis and behaviour for one measurement station in Cáceres.

The predictive capacity that the seven highest harmonic components have for estimating long-term indicators is analysed in Table II. The mean of the differences (in absolute value) between the estimate of each long-term indicator and the observed indicator is analysed. In the first row, the estimate of each long-term indicator was obtained by using the

TABLE I. Amplitudes of the continuous and harmonic components.

i	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
k	1	1	1	1	1	1	1	2	2	2	2	2	2	3	3	3	4	4	4	4	4	4	5	5	5	5	2	2	4
A_0	82.0	80.8	79.8	82.0	79.0	79.4	81.2	77.5	75.3	75.9	78.4	79.0	78.6	72.5	73.0	73.4	69.3	70.4	67.3	70.1	68.6	67.9	65.8	67.8	67.7	65.3	65.9	61.8	56.0
A_1	0.2	0.2	0.4	0.3	1.0	0.4	0.3	0.3	0.3	0.4	0.3	0.2	0.3	0.4	0.3	0.6	0.3	0.4	0.4	0.6	1.9	0.5	0.8	0.3	0.2	0.4	0.4	0.3	0.5
A_6	0.2	0.8	0.7	0.6	0.7	0.4	0.6	0.7	0.5	0.5	0.3	0.4	0.3	0.6	0.6	0.6	0.2	0.4	0.6	0.7	0.9	0.8	0.5	0.3	0.4	0.6	0.3	0.3	0.5
A_7	1.5	2.7	2.3	2.4	2.7	1.9	1.8	3.0	2.4	2.6	2.7	3.1	2.7	3.0	2.7	2.5	2.1	2.1	3.2	2.1	2.8	2.7	3.9	2.4	2.7	2.9	2.0	2.6	1.7
A_8	0.3	0.5	0.6	0.6	1.1	0.4	0.5	0.7	0.7	0.2	0.2	0.5	0.3	0.5	0.5	0.6	0.2	0.3	0.5	0.3	0.6	0.7	0.5	0.3	0.2	0.3	0.5	0.4	0.6
A_{14}	1.1	1.3	1.2	1.3	1.2	1.3	1.3	1.6	1.1	1.4	1.5	1.8	1.6	1.5	1.5	1.1	1.2	1.2	1.8	1.1	1.4	1.6	2.3	1.1	1.1	0.9	1.1	1.3	1.0
A_{21}	0.3	0.2	0.2	0.4	0.3	0.5	0.4	0.2	0.2	0.3	0.8	0.3	0.5	0.4	0.2	0.1	0.4	0.1	0.4	0.2	0.7	0.4	0.7	0.1	0.3	0.2	0.3	0.3	0.4
A_{28}	0.2	0.4	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.3	0.3	0.5	0.4	0.4	0.4	0.3	0.7	0.3	0.3	0.2	0.5	0.5	0.7	0.4	0.4	0.5	0.3	0.3	0.4

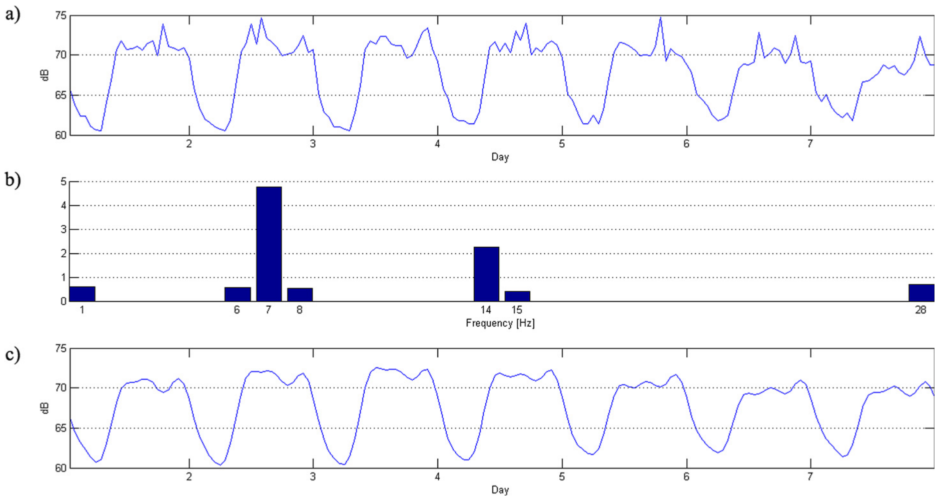

FIG. 2. (Color online) Example of FFT analysis for station 24. (a) Weekly noise signal integrated hour by hour [$L_{Aeq,1h}$]; (b) amplitudes of the first and the highest harmonic components; (c) noise level estimated by inverse FFT.

seven highest harmonic components for each station (together with the continuous component). The error is the standard deviation. In the second row, long-term parameters are estimated by using the averaged components of all the stations of Cáceres used in this study.

It can be observed that the values obtained in the second case (row 2) are higher than those obtained in the first case (row 1), but in all cases they are close to 1 dB or less. In addition, it should be noted that we are analysing the predictive ability of the Fourier components of the values of the weekly indicators, not annually. This aspect will be discussed in Sec. III B. Nevertheless, it should be considered that this methodology should not be used in this stage of development, for the estimation of acoustics indicators for periods less than a week. Therefore, with a single model, the mean errors obtained in the predictions are quite acceptable, finding average values of approximately 1 dB for all the acoustic indicators. Therefore, the results seem to indicate the existence of mean amplitudes of the harmonic components of Fourier analysis that, regardless of the type of urban road in question, could be used to estimate the acoustic indicators of any street, provided the value of the continuous component of that street is known.

If the mean of the seven highest Fourier components found could be considered as valid for similar cities, it is possible to assume that the Fourier components obtained by using the measurement stations of the city of Cáceres can be used as the Fourier components in the city of Talca ($i = [27–29]$). This fact implies that the intercity variations on the temporal distribution of the noise have no effects on the indicators. In Table II, for the city of Talca, the mean values of the differences of the long-term parameters estimates with its own components (row 3) and with the mean components obtained for Cáceres (row 4) are presented. It can be noted that the results are, again, higher for the mean component. It can be seen that the differences are quite acceptable if those previously obtained (row 2) for the city of Cáceres using the mean amplitudes of the components are considered.

Given the relative importance of the two components of greatest amplitude (A_7 and A_{14}), the above analysis has been repeated, but only considering these two components. That is, we analysed the predictive capacity first for themselves, then the average in Cáceres, and finally, the average in Talca. The results are shown in Table III.

It is very interesting to note that the results are quite similar to those presented in Table II. The difference in the results between Tables II and III is 0.3 dB as much and, in some cases, the result is the same. Therefore, it appears that from these results, it could be inferred that by using their own continuous component associated with the traffic noise of the urban road under study, together with the average amplitudes of the two Fourier highest harmonic components obtained in another city, it is possible to estimate the weekly noise for traditional indicators, L_d, L_e, L_n, L_{dn}, and L_{den}, with mean errors of about 1 dB.

If the results are analysed according to the categorisation method[18,19] (k index in Table I), some tendencies can be observed. In this sense, an analysis of the predictive ability was made dividing the stations into categories so that the mean components were taken from each category. The five categories were gathered into three groups because there is

TABLE II. Mean of the differences (in absolute value) between the estimate of each long-term indicator and the observed indicator [dB] for the seven highest harmonic components. L_d: equivalent continuous sound pressure level registered in the diurnal period (from 7.00 to 19.00) (Ref. 40). L_e: equivalent continuous sound pressure level registered in the evening period (from 19.00 to 23.00) (Ref. 40). L_n: equivalent continuous sound pressure level registered in the night period (from 23.00 to 7.00) (Ref. 40). L_{dn}: day-night level (Ref. 15). L_{den}: day-evening-night level (Ref. 15).

Mean differences	ΔL_d	ΔL_e	ΔL_n	ΔL_{dn}	ΔL_{den}
$\Sigma i\ \forall i = [1\text{-}26] - 7$ own comp.	0.3 ± 0.2	0.2 ± 0.4	0.5 ± 0.3	0.4 ± 0.2	0.3 ± 0.2
$\Sigma i\ \forall i = [1\text{-}26] - 7$ mean comp.	0.7 ± 0.6	0.9 ± 1.2	1.1 ± 0.9	0.8 ± 0.6	0.8 ± 0.5
$\Sigma i\ \forall i = [27\text{-}29] - 7$ own comp.	0.3 ± 0.2	0.2 ± 0.2	0.5 ± 0.3	0.4 ± 0.1	0.4 ± 0.1
$\Sigma i\ \forall i = [27\text{-}29] - 7$ mean Các. comp.	0.6 ± 0.3	0.5 ± 0.3	1.4 ± 1.1	0.7 ± 0.3	0.5 ± 0.3

TABLE III. Mean of the differences (in absolute value) between the estimate of each long-term indicator and the observed indicator (in dB) for the two highest harmonic components.

Mean differences	ΔL_d	ΔL_e	ΔL_n	ΔL_{dn}	ΔL_{den}
1. $\Sigma i\ \forall i = [1\text{-}26] - 2$ own comp.	0.6 ± 0.4	0.4 ± 0.3	0.8 ± 0.7	0.6 ± 0.4	0.5 ± 0.4
2. $\Sigma i\ \forall i = [1\text{-}26] - 2$ mean comp.	0.8 ± 0.6	0.9 ± 1.2	1.1 ± 1.0	0.9 ± 0.6	0.8 ± 0.5
3. $\Sigma i\ \forall i = [27\text{-}29] - 2$ own comp.	0.5 ± 0.1	0.2 ± 0.2	0.7 ± 0.4	0.6 ± 0.2	0.5 ± 0.2
4. $\Sigma i\ \forall i = [27\text{-}29] - 2$ mean Các. comp.	0.6 ± 0.4	0.5 ± 0.3	1.4 ± 1.1	0.8 ± 0.3	0.6 ± 0.3

little data available in each category; the reason for this grouping is the similarity between the amplitudes of the binned categories. Table IV shows the results where A: $k = 1$, B: $k = 2$, 3 and 4, and C: $k = 5$. The first results correspond to two global mean components and the second ones correspond to two mean components by group of categories. In the case of groups A and B the mean errors found are, in general, lower than 1 dB. The greatest variability is found in category 5 for all indicators. When the analysis is done by the components obtained from the average for each category, at large amplitudes, one can see similar results or even a small improvement to the predictions obtained through the global average values, except for the L_e index in the C group. This may be because the errors obtained with the global average components are already very low. However, it may also be that the spatial stratification by categories affects the values of the indicators, but to a lesser extent, affects the temporal structure of urban noise. Other studies have already found minor differences between the strata associated with global values of noise levels when the temporal evolution of urban noise in points with different city characteristics is analysed.[11,21,37]

B. Analysis of the potential of weekly measurements to estimate annual indicators through Fourier analysis

In the previous subsection, the ability of Fourier analysis was assessed to estimate the values of weekly noise indicators L_d, L_e, L_n, L_{dn}, and L_{den}, from the continuous component itself as well as the amplitudes of the components obtained from the mean values of the measures made at different points. Moreover, it was observed that the values of the amplitudes of the periodic components are relatively uniform in points with very different urban characteristics and traffic flow. This subsection will analyse the capacity that the weekly measurements may have to estimate the values of the indicators measured for a full year. To do this, the 2006 and 2010 annual data were obtained and the predictive ability of the weekly measurements for annual values obtained for these years was studied.

Table V shows the continuous and periodic components of Fourier analysis for the years 2006 (columns 3 and 4) and 2010 (columns 5 and 6). These values correspond to the average values for the different weeks making up such years. The low dispersion of the average values obtained, regardless of the year, indicates a high stability in the amplitudes of the Fourier analysis components during different weeks of the year. In this respect, it is of special interest to note that 2010 had some anomalous circumstances discussed elsewhere[41] because of the victory of the Spanish soccer team in the World Cup. Nevertheless, the effect of these events on Fourier analysis does not seem significant. Furthermore, it can be seen that the average values obtained are similar to those shown in Table I for the analysis of periodic Fourier components in the case of weekly measurements at different points of two cities belonging to different countries. These values are summarised in columns 7 and 8 in Table V.

Given these results, the ability of weekly measurements to estimate annual indicators was analysed. To do this, first, the variability of the continuous components of the Fourier analysis for the weeks in the two years under consideration was analysed.

In this sense, the value of the weekly continuous component (A_{0W}) was calculated in order to compare it with the value of the annual continuous component (A_{0Y}). For 2006, the average value of the absolute differences between the annual and weekly value is 0.6 dB with a standard deviation of 0.4 dB, with 95% of the weekly A_{0W} within the range $A_{0Y} \pm 1.3$ dB. For 2010, the average value of the absolute differences between the annual and weekly value is 0.5 dB with a standard deviation of 0.3 dB; 95% of weekly A_{0W} are in the range $A_{0Y} \pm 1.1$ dB. Also, if an annual continuous component is calculated by taking the years 2006 and 2010 together (A'_{0Y}), the mean absolute difference between this

TABLE IV. Mean of the differences (in absolute value) between the estimate of each long-term indicator and the observed indicator (in dB) if the results are grouped as a function of the category.

Mean differences	Groups	ΔL_d	ΔL_e	ΔL_n	ΔL_{dn}	ΔL_{den}
2 global mean comp.	A:1	0.8 ± 0.7	0.4 ± 0.3	1.3 ± 1.0	0.9 ± 0.5	0.7 ± 0.3
	B:2,3,4	0.7 ± 0.4	0.8 ± 0.7	1.0 ± 0.7	0.8 ± 0.5	0.8 ± 0.5
	C:5	1.0 ± 0.9	2.5 ± 2.4	1.3 ± 1.8	1.1 ± 1.1	1.0 ± 0.8
2 categ. mean comp.	A:1	0.9 ± 0.9	0.4 ± 0.4	1.0 ± 1.0	0.8 ± 0.5	0.7 ± 0.3
	B:2,3,4	0.6 ± 0.4	0.6 ± 0.6	1.0 ± 0.7	0.8 ± 0.5	0.7 ± 0.5
	C:5	0.8 ± 0.8	3.0 ± 1.7	1.3 ± 1.9	1.1 ± 1.1	1.3 ± 0.8

TABLE V. Weekly average values (in dB) for the different components of Fourier analysis for 2006, 2010, and all measurements points.

		2006		2010		Weekly average at different points	
Hours of the period	Component	μ	σ	μ	σ	μ	σ
	A_0	62.4	0.7	62.7	0.6	–	–
168	A_1	0.5	0.2	0.5	0.2	0.4	0.3
28	A_6	0.5	0.2	0.5	0.2	0.5	0.2
24	A_7	2.6	0.3	2.8	0.3	2.6	0.5
21	A_8	0.5	0.1	0.5	0.1	0.5	0.2
12	A_{14}	1.5	0.2	1.7	0.2	1.4	0.3
8	A_{21}	0.2	0.1	0.2	0.1	0.3	0.2
6	A_{28}	0.5	0.1	0.4	0.2	0.4	0.1

A'_{0Y} and the weekly A_{0W} values is 0.6 dB with a standard deviation of 0.4 dB; 95% of A_{0W} values are within $A'_{0Y} \pm 1.2$ dB. Therefore, it is worth noting that the value of the continuous component of the Fourier analysis for the different weeks, even in a time interval of four years, is stable.

Thus, after this very stable result for the value of the weekly continuous component over a year, we will analyze the capacity of the weekly harmonic components to estimate the annual indicators. Table VI shows the results for 2006 and Table VII for 2010. The average values and their deviations are shown, as well as the range in dB that is required for 95% of the data within this range when the actual value of the indicator obtained from all annual series measured at each year is taken as reference. The values shown were obtained using the continuous components of each week; that is, the component that is actually known. In addition, as discussed above, we considered the possibility of using the value of the mean periodic components of the week.

If we look at 2006, it is noteworthy that despite the predictions improves with the use of the 7 mean components, the value of the predictions obtained from two own components is very good. The average error is only 1 dB or less in all long range indicators. Moreover, 95% of the data lies within an error of about 2 dB. Looking at the year 2010, the results of the predictions are not as good. Nevertheless, we must remember that this year was abnormal. An increase caused by the World Cup was 0.7 dB in the annual L_e and 0.2 dB in the annual L_{den} was reported.[41] With this error correction, it can be seen that these indicators have errors in 2010 similar to those of 2006. Therefore, the Fourier analysis has another important advantage—not introducing into the predictions anomalous events that occur at a measuring point and do not come from the analysed sound source (in this case, road traffic), but affect the overall noise level.

To understand the importance of the results obtained, it is essential to note that at all times we have used the continuous component of the week concerned, which is the value to be measured. In addition, errors made in the estimate of the annual indicators by using only the amplitudes of the two highest harmonic components are, for both years and all annual indicators studied, quite similar to those obtained by using the average amplitudes of the seven most important harmonic components.

These results indicate the potential of Fourier analysis for understanding the temporal variability of the urban noise associated with road traffic and for predicting long-term indicators. The use of a single week as reference time measurement allows to estimates the indicators with uncertainties between 1 and 2 dB. In addition, the results indicate the possibility of eliminating the contribution of anomalous events not associated with the basic source under study (road traffic in this case).

Finally, as it has been proven, the continuous component is the only one that allows one to differentiate the values that long-term sound indicators have at different measurement points. This could open up new application so that the continuous variable can be estimated from models that take into account either demographic variables[20,42,43] or the type of roads[11,21] or even urban characteristics[44] with consequent reduction in costs that this could imply in conducting initial estimates of the indicators of long duration, for example, in the sense proposed by Schomer *et al.*[43]

TABLE VI. Predictive potential that the one week Fourier components have to estimate the annual indicators for the year 2006 (in dB).

	7 own comp.			7 mean comp.			2 own comp.			2 mean comp.		
Year 2006	μ	σ	95%	μ	σ	95%	μ	σ	95%	μ	σ	95%
ΔL_d	0.8	0.6	2.2	0.7	0.5	1.8	0.9	0.7	2.3	0.8	0.6	1.8
ΔL_e	0.7	0.5	1.6	0.6	0.4	1.7	0.9	0.6	1.8	0.7	0.5	1.7
ΔL_n	1.0	0.6	2.1	1.0	0.6	2.1	1.0	0.6	2.1	1.0	0.6	2.1
ΔL_{dn}	0.9	0.6	1.8	0.8	0.6	1.9	0.9	0.6	1.8	0.9	0.6	1.9
ΔL_{den}	0.8	0.6	1.7	0.8	0.5	1.9	0.9	0.6	1.8	0.8	0.6	1.9

TABLE VII. Predictive potential that the one week Fourier components have to estimate the annual indicators for the year 2010 (in dB).

	7 own comp.			7 mean comp.			2 own comp.			2 mean comp.		
Year 2010	μ	σ	95%	μ	σ	95%	μ	σ	95%	μ	σ	95%
ΔL_d	0.9	0.6	2.1	0.9	0.6	1.9	1.0	0.7	2.3	1.0	0.6	2.0
ΔL_e	0.7	0.5	1.5	0.7	0.6	1.7	0.9	0.5	1.8	0.9	0.6	1.9
ΔL_n	1.8	0.8	2.9	1.9	0.6	2.9	1.8	0.7	2.9	1.8	0.6	2.8
ΔL_{dn}	1.2	0.6	2.2	1.3	0.6	2.3	1.3	0.6	2.3	1.3	0.6	2.4
ΔL_{den}	1.0	0.6	2.0	1.1	0.6	2.2	1.2	0.6	2.1	1.2	0.6	2.3

IV. CONCLUSIONS

For the study of urban noise, Fourier analysis was carried out on samples of measurements of sound levels for one week, obtained at points from the five categories used by the categorisation method.

The results indicate the potential of Fourier analysis for understanding the temporal variability of the urban noise associated with road traffic and for predicting long-term indicators from measurements of a week.

It has been found that regardless of the urban characteristics of the measurement environment and the associated traffic flow, periodic components of greater amplitude and values of the amplitudes are similar in the different samples.

In this regard, it is noteworthy that the most important components obtained from FFT analysis between such distant cities as Cáceres (Spain) and Talca (Chile) are stable.

An estimate of annual values from weekly measurements was obtained from the method of analysis of urban noise proposed here, with an error that can be less than 2 dB, i.e., the error that is usually accepted in the noise maps obtained using noise prediction software.

Finally, the results indicate the possibility of eliminating the contribution of anomalous events not associated with the basic source under study.

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