Elsevier Editorial System(tm) for Science of the Total Environment
Manuscript Draft

Manuscript Number: STOTEN-D-13-00381R1

Title: URBAN STREETS FUNCTIONALITY AS A TOOL FOR URBAN POLLUTION MANAGEMENT

Article Type: Full Length Article

Keywords: noise pollution
sampling methods
urban planning

Corresponding Author: Dr. Juan Miguel Barrigón Morillas, PhD

Corresponding Author's Institution: University of Extremadura

First Author: Guillermo Rey Gozalo, Ph.D.

Order of Authors: Guillermo Rey Gozalo, Ph.D.; Juan Miguel Barrigón Morillas, PhD; Valentín Gómez Escobar, Ph.D.

Abstract: Pollution derived from traffic can be considered one of the major problems of modern cities. Although considerable efforts have been devoted to gathering information about pollution and its control, little attention has been paid to the analysis of relationships between pollution distribution and town planning. The existence of these relationships would enable better prediction and prevention of pollution through town planning. In this work, an analysis of one pollutant derived from traffic (urban noise) in 27 cities is presented. Non-parametric tests and ROC analyses were employed, using the equivalent sound level (Leq) values as the dependent variable. For the characterization of the pollutant, an alternative concept to accessibility is analyzed: the concept of functionality.
Results of statistical inferential analysis showed the existence of significant differences between the sound levels of the different categories results, confirming that noise is stratified in the studied cities and that the five categories proposed based in the concept of functionality highlight this noise stratification. Moreover, high sensitivity and low non-specificity were obtained by using ROC analysis. Results of this analysis also showed an overall average value of prediction capacity close to 90%. Therefore, because the proposed categories highlight the noise stratification of the studied pollutant in all the towns studied, the functionality concept can be considered an interesting tool for urban planning and for designing pollution prevention policies. Finally, as traffic is a source of other urban pollutants, the concept of functionality may be a new concept for wide environmental pollution management.

Response to Reviewers: Reviewer #1: This paper is well structured and can be accepted for publication in your magazine. But in my opinion, it is necessary to make some improvements that can be grouped into two blocks:

1 Document structure
- 1.1 Page 10, line 8, Table II must be Table I.
- 1.2 Page 11, lines 44-46, parentheses should be used.
- 1.3 Figures 2 and 3 should improve their axes.
- 1.4 Figures 3, 4 and 5 must be 2, 3 and 4.

URBAN STREETS FUNCTIONALITY AS A TOOL FOR URBAN POLLUTION MANAGEMENT

Guillermo Rey Gozalo, Juan Miguel Barrigón Morillas*, Valentín Gómez Escobar

Acoustic Laboratory, Department of Applied Physics, Polytechnic School, University of Extremadura. Avda. de la Universidad s/n, 10003 Cáceres, Spain.

*Corresponding author: Tel.: +34 927 257 195. Fax: +34 927 257 203. E-mail address: barrigon@unex.es

ABSTRACT

Pollution derived from traffic can be considered one of the major problems of modern cities. Although considerable efforts have been devoted to gathering information about pollution and its control, little attention has been paid to the analysis of relationships between pollution distribution and town planning. The existence of these relationships would enable better prediction and prevention of pollution through town planning. In this work, an analysis of one pollutant derived from traffic (urban noise) in 27 cities is presented. Non-parametric tests and ROC analyses were employed, using the equivalent sound level (L_{eq}) values as the dependent variable. For the characterization of the pollutant, an alternative concept to accessibility is analyzed: the concept of functionality.

Results of statistical inferential analysis showed the existence of significant differences between the sound levels of the different categories results, confirming that noise is stratified in the studied cities and that the five categories proposed based in the concept of functionality highlight this noise stratification. Moreover, high sensitivity and low non-specificity were obtained by using ROC analysis. Results of this analysis also showed an overall average value of prediction capacity close to 90%. Therefore, because the proposed categories highlight the noise stratification of the studied pollutant in all the towns studied, the functionality concept can be considered an interesting tool for urban planning and for designing pollution prevention policies. Finally, as traffic is a source of other urban pollutants, the concept of functionality may be a new concept for wide environmental pollution management.

Keywords: noise pollution, sampling methods, urban planning.

1. INTRODUCTION

One of the major consequences of globalization has been the continuous increase in the population of urban centers. Cities have become in the most successful habitat model for human civilization. Development patterns have changed from compact urban areas, with a strong central business district and industrial facilities serving as large employment centers, to metropolitan areas that extend over large areas and in which employment is frequently widely scattered (EPA, 2001; EEA, 2009). People must rely on automobiles for access to jobs and services because residential and commercial areas are separated. This increase in vehicle travel and vehicle dependency has not only contributed to an increase in greenhouse gases but has also produced an increase in annoying noise and noisy environments (Babisch, 2006; Belojevic et al., 2008; Iosub et al., 2008; Pathak et al., 2008; Paunović et al., 2009; Szeremeta and Zannin, 2009; Di et al., 2012; Halonen et al., 2012). Recent publications from international organizations indicate that noise pollution is a major environmental problem that affects a large part of the world population and represents a risk to our health and quality of life (EEA, 2009; WHO, 2011).

The importance of the urban form on sustainable development has been recognized in recent years and determines transportation demands, which directly affect noise and air pollution (Sheng and Wa Tang, 2011). Some researchers have studied the spatial relationship between urban shapes and morphologies and air pollution and noise (Bowker et al., 2007; Su et al., 2008, Albert and Liu, 2010; Can et al., 2011a, 2011b; Foraster et al., 2011; Guedes et al., 2011; Wang and Kang, 2011; Freitas et al., 2012; Salomons and Berghauser Pont, 2012).

Currently, accessibility is a concept that is widely used in a number of scientific fields, including transport planning, urban planning and geography. As a result, land-use and infrastructure policy plans are often evaluated with accessibility measures that are easy to interpret for researchers and policy makers but that have strong methodological disadvantages (Geurs and van Wee, 2004).

In this work, an alternative concept to accessibility for use in transport planning, urban planning and environmental pollution management is analyzed: the concept of functionality. This concept involves the consideration of the functionality of the streets of the city as a communication path between different parts of the city and between the city and other urban areas. In addition, other variables such as the flow of vehicles, the type of traffic, the average speed and others may have a clear relationship with functionality. Consequently, functionality may be associated with the pollution that is related to road traffic (both acoustical and chemical). Previous works have analyzed the relationship between traffic and pollutants (physical, such as noise, or chemical) (Barrigón et al., 2005, Su et al., 2008, Can et al., 2011a, 2011b; Foraster et al. 2011). Therefore, the concept of functionality can be a very useful tool for the prediction and control of physical and chemical urban pollution and for improving urban planning policy.

To date, the concept of functionality has been rarely used to study pollution in cities. In this sense, our research group has been working on the development of a methodology that allows us to establish statistically significant relationships between the functionality of the urban streets and noise pollution, which we call the categorization method. It has been demonstrated that categorization is adequate for the description of noise in medium-sized cities (Barrigón et al., 2005) and clearly has a better prediction capacity than the *standarized grid method* (Barrigón et al., 2011, Rey Gozalo et al., 2012).

In the present work, an analysis of the relationship among the functionality of urban streets and noise pollution is performed for urban areas that range from small towns of approximately 2,000 inhabitants to more populated cities of almost 700,000 inhabitants, with a total of 27 cities studied. These analyses focused on the verification of the proposed categories, which highlight noise stratification, and on the prediction capacity of the method. Although this analysis is focused on noise, it is expected that the results can be extrapolated to other types of pollution produced by traffic.

Section 2 describes the method and the cities in which it was applied. Section 3 presents and discusses the results. Finally, Section 4 presents the most relevant conclusions.

2. METHODS

2.1. The studied cities

In the present work, 27 different cities were studied, with 25 cities located in various regions of Spain as well as one each in Chile (Valdivia) and Portugal (Campo Maior). Table I shows different data of the studied cities. The studied cities present different characteristics with respect to:

- Location: coastal cities (Santander, Málaga and Valdivia), cross-border cities (Campo Maior, Olivenza and Badajoz) and interior cities (the rest of the cities).
- Administrative relevance: high administrative relevance cities such regional capital cities (Mérida, Valladolid, Sevilla, Santander and Vitoria), medium administrative relevance cities such as province capitals cities (Cáceres, Badajoz, Sevilla, Málaga, Salamanca, Valladolid, Santander and Vitoria), and the rest of the cities with low administrative relevance.
- Urban area: varying from 59.27 km^2 (Sevilla) to 0.57 km^2 (La Coronada).
- Population (INE 2008, 2010): varying from 699,759 inhabitants (Sevilla) to 2,238 inhabitants (La Coronada). The Spanish cities included in this study comprise nearly 6% of the entire population of Spain. There are 8 cities with populations greater than 100,000 inhabitants (Valdivia, Badajoz, Salamanca, Santander, Vitoria, Valladolid, Málaga and Sevilla) while the rest (19 cities) are under this number of inhabitants. Note that an important part of the world population lives in cities under 100,000 inhabitants (68% of the world in 2003)

These differences between the studied cities reflect the existence of important town planning differences that allow for a more complete verification of the validity of the categorization method as a tool that demonstrates the relationship between the functionality concept and the existence of a stratification in one of the pollutants associated with urban traffic (noise).

2.2. The *categorization method*

As previously mentioned, the categorization method classifies the urban roads according to their communication function and develops the following steps: (a) Definition of the categories. (b) Assigning the town's streets to these categories. (c) Selection of sampling points. (c) Decision on the number of samples and sampling schedule. (d) Sampling. (e) Analysis of the results and confirmation of the initial hypothesis.

For the first step (definition of the categories), we used the following definitions:

- *Type 1* includes those preferred streets whose function is to form connections with other Spanish towns and to interconnect those preferred streets. In general, these streets are indicated by a system of road signs.
- *Type 2* includes 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 preferred streets as defined in Type 1, above. This category also includes streets normally used as alternatives to Type 1 streets in the case of traffic saturation.
- *Type 3* includes streets that lead to regional roads, streets that provide access from those streets 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* includes all other streets that clearly allow communication between the three previously defined types of street, as well as 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.
- *Type 6* comprises all the pedestrian-only streets.

As the assumption behind this method of street categorization is that traffic is the most important source of noise pollution, the sixth category was not included in the present study. In any case, pedestrian-only streets usually represent a very small percentage of all the streets in a city.

For the second step (assigning the town's streets to these categories), basic information about the city was obtained, including plans, areas of interest that imply movements of a great number of citizens (entertainment, bureaucratic, commercial, industrial, residential, etc. centers), and traffic restrictions. From this information, a first assignment was performed. Assignments were modified or confirmed after visiting the cities and speaking with citizens.

For the third step (sampling point selection), points of streets belonging to each category were randomly selected. Two methods were used: for streets in categories 1 to 4, the total street length was calculated, and using a "random" function, different non-equivalent sampling points were selected. Equivalent points are those located on the same section of a street with no important intersection between them. Streets and points were selected for each category. In the case of category 5, due to the large number of streets involved, each administrative-level street was taken to be a single potential sampling point, with the actual measurement made in the middle of the segment that corresponded to the entire street. When possible, 10 points were chosen per category. Sometimes in small towns, a lower number was chosen, with at least 6 points per category.

For the fourth step (decision on the number of samples and sampling schedule), all the measurements included in this work were performed from 7:00 to 19:00 on working days in the years 2005 to 2011. At each sampling point, three or four 15-minute measurements were performed on different days of the week and at different time intervals. The diurnal period (7:00 to 19:00) was divided into three or four intervals, and each measurement of the sampling point was performed in one of these intervals.

For the fifth step (sampling), all measurements were performed following the ISO 1996-2 guidelines (ISO 1996-2, 2007) using 2236, 2238 or 2250 Brüel&Kjaer type-I sound-level meters with a tripod and windshield. Calibration was performed using a 4231 Brüel&Kjaer calibrator. The sound-level meter was located one meter from the curb. The volume of traffic was visually determined and classified (cars, heavy vehicles, and motorcycles) during sampling. Other relevant information (noise sources, meteorological conditions, street dimensions, road surface type, conservation of the road surface, etc.) was also noted.

For the sixth step (analysis of the results and confirmation of the stratification), the measured data were processed by calculating the noise value at each sampling point, which was performed by averaging the sound energy results for the measurements performed at each point. Different analyses were then carried out as described in the following section.

In additionally to the previous six steps, in this work, we investigated the prediction capacity of the method and other characteristics that would be necessary for applying the method to urban noise management and planning purposes. Additionally, given the above-mentioned good correlations generally observed between noise levels, traffic conditions and pollutant concentrations (Chen et al., 2008; Vlahogianni et al., 2011), the results of this method might also be applied in the decision-making process in the fight against chemical pollution.

2.3. Statistical analyses

The continuous equivalent sound level (L_{eq}) was chosen for the different statistical tests used to analyze the results and evaluate the quality of the category classification because L_{eq} is most commonly used in noise studies. L_{eq} is also used to calculate other noise indicators, such as L_{DN} and L_{DEN}, which are preferred by some of international regulations (ANSI, 1996; COM, 2002).

From the calculated sound values at each sampling point, the average value and the standard deviation of the five studied categories was calculated for all cities. These values provided preliminary information about the differences between the categories and between the evaluated cities. These results were contrasted by inferential analysis.

For the analysis of the *categorization method,* two groups of statistical tests were chosen, all of them implemented in the shareware R Project.

In the first group, comparison of sound level values for each category was performed for each city to determine whether the proposed classification enabled a significant description of the stratification of noise in the city. The hypotheses were as follows:

- Null hypothesis (H_0): There are no significant differences between the L_{eq} values (dBA) of the different categories.
- Alternative hypothesis (H_1): There are significant differences between the L_{eq} values (dBA) of the different categories.

The small number of samples made it doubtful that the contrasts were from a normal population, and thus, nonparametric rather than parametric tests were used. To address the previous hypotheses at a probability of at least 95%, that is, with a degree of significance (α) equal to 0.05, the nonparametric Kruskal-Wallis and Mann-Whitney U-tests were used.

The Kruskal-Wallis test (Kruskal and Wallis, 1952) was used for comparison of the five categories to determine any significant differences. When these differences were found, as they were in all cities, as shown below, Mann-Whitney U-tests were used to compare pairs of categories.

The Mann-Whitney U-test (also called Mann-Whitney-Wilcoxon test or Wilcoxon test or Wilcoxon-Mann-Whitney test) is a nonparametric test for assessing whether two independent samples or observations come from the same distribution (Wilcoxon, 1945; Mann and Whitney, 1947). This test was used to compare pairs of separate categories within the same population. To avoid any errors due to the use of data from the same population rather than from randomly selected data, the Holm correction was used (Holm, 1979).

In the second group of statistical tests, we used the Receiver Operating Characteristics (ROC) analysis to study the predictive capacity and other characteristics that refer to the classification capacity of this method (Hand and Till, 2001; Fawcett, 2006, Torija and Ruiz, 2012). ROC analysis allows us to establish the upper and lower limits of the sound levels assigned to each category, calculate the sensibility (capacity to include previously assigned streets in the stratum), non-specificity (proportion of streets that were not initially assigned to a certain stratum but that the ROC analysis indicated belonged to that stratum), and predictive values (proportion of the streets that the ROC analysis assigned to a stratum that matched the categories to which they were initially assigned, relative to the total number of streets that the ROC analysis determined for the stratum) from the following equations:

$$sensibility = \frac{number\ of\ data\ classified\ correctly\ in\ category\ i}{number\ of\ data\ in\ category\ i} \quad (1)$$

$$non - specificity = \frac{number\ of\ data\ classified\ incorrectly\ in\ category\ i}{number\ of\ data\ that\ do\ not\ belong\ to\ category\ i} \quad (2)$$

$$predictive\ value = \frac{number\ of\ data\ classified\ correctly\ in\ category\ i}{number\ of\ data\ that\ the\ ROC\ method\ includes\ in\ category\ i} \quad (3)$$

The ROC analysis allowed us to analyze the stratification of sound values by considering the percentage of correctly classified values (sensibility and predictive value) and the number of incorrectly classified values (non-specificity). It is an alternative test that allows us to contrast the results of inferential analyses and achieves a better evaluation of the performance of the *categorization method*.

3. RESULTS AND DISCUSSION

3.1. Mean and global results

As a first step, the mean values of the five categories were calculated for each studied city (Table II). As observed, in two of the studied cities (Arroyo de la Luz and Coria), their town planning structure did not allow assigning of any streets to category 2.

As observed in Table II, for all the cities, there was an increase in the mean noise levels as the category number decreased. There was generally a difference between the mean values of adjacent categories near 3 dB and sometimes (usually between categories 4 and 5) differences of 8 dB or more. Sometimes, the observed difference was small, which may have indicated a possible overlap in the results of the categories. The mean values and standard deviations of the differences between categories were 2.4 ±

1.2, 2.1 ± 0.9, 3.5 ± 1.2, and 5.8 ± 1.8 dBA for differences between categories 1 and 2, categories 2 and 3, categories 3 and 4, and categories 4 and 5, respectively. As mentioned above, the highest differences were found between categories 4 and 5.

We also observe in Table II that the standard deviations obtained for the mean noise values of the different categories of the studied cities were generally small for the first four categories (mean values of 1.6 ± 0.8, 1.4 ± 0.6, 1.6 ± 0.7, and 1.8 ± 0.7 dBA for categories 1 to 4, respectively), indicating a high homogeneity in the sound values of the streets included in these four categories in each city. In contrast, the standard deviation was higher in category 5 (mean value of 2.9 ± 0.9 dBA), as previously described (Barrigón el al. 2005; Romeu et al., 2006). This result was likely due to the great variety of form, inhabitants, location, type, and use of these streets.

Comparing results shown in Table II with some international references, we can see that none of the mean measured values were under 50 dBA, considered by the WHO as moderate annoyance (WHO, 1999) and only in the category 5 of four cities (Castuera, Coria, Campo Maior and Trujillo) mean measured noise levels were under 55 dBA, a level that the WHO considers as a serious annoyance (WHO, 1999). Note that these cities are not the less populated or the ones with less surface or density. If we now consider the 65 dBA value [the value that the OECD suggests as the daytime exposure limit (OECD, 1986)] the mean values of categories 1, 2 and 3 were generally above this reference level (100%, 96% and 70 %, respectively) but only 37% and 4% of the mean values of categories 4 and 5, respectively, were above this reference level. The only city in which category 5 mean value was higher than 65 dBA was Santander which is not the most populated studied city.

3.2. Study of the stratification of noise levels values for the different categories

The observed differences between the different categories, shown in Table II, were analyzed by inferential analysis using the Kruskal-Wallis and Mann-Whitney U-tests.

The results of the Kruskal-Wallis test for the different cities produced p-values from $2.54{\cdot}10^{-6}$ to $3.60{\cdot}10^{-9}$, indicating that in all the studied cities, there were significant differences ($p \leq 0.001$) between the values of the different categories. The existence of these significant differences between categories in all the cities made it reasonable to look for significant differences among each pair of categories using the Mann-Whitney U-test with the Holm correction. The results of this test are shown in Table III.

As observed, a major proportion of comparisons of the pairs of categories are significantly different at a confidence level of 95% or higher. Only in 7.5% of the comparisons was a non-significant difference found, indicating an overlap between the categories. The possible overlaps detected were always between adjacent categories, except in the city of Trujillo, where an overlap between categories 1 and 3 was found. The rest of the overlaps were primarily between categories 1 and 2 and categories 2 and 3. Only one overlap was observed between categories 3 and 4, and no overlaps were observed between categories 4 and 5. In 14 of the 27 studied cities, there were no overlaps between any categories, and only one overlap was observed in 8 cities.

These results confirmed that the proposed definition of the categories highlighted the stratification of urban noise. Thus, it seems clear that noise in our apparently chaotic cities had a linear and spatial internal structure that could be highlighted and used for other purposes, such as urban design, noise mapping, noise estimation in non-measured streets, etc.

Therefore, the application of the concept of functionality to the definition of street categories allows us to demonstrate the existence of a stratification of a contaminant such as noise. Given the relationship between this contaminant and other related chemical pollutants related to traffic, the concept of functionality and these defined categories may provide new strategies for the study of pollution in cities and new methodologies for urban management and planning.

3.3. ROC analysis

To enhance the analysis of the differences between the categories, ROC analysis was used to analyze additional characteristics of each category, such as sensibility, non-specificity and predictive capacity.

In Figure 1A, the mark (mean value of the upper and lower limits for each category) of the different categories is shown. In Figure 1A, we observe that, as observed for the mean values of the categories (Table I), the mark values of the different categories decreased from the first to the fifth categories for all of the cities studied. Comparing the mean differences between the mark values for the categories (3.0±1.0, 2.2±0.6, 3.5±0.8, and 6.3±1.7 dBA for the differences between categories 1 and 2, categories 2 and 3, categories 3 and 4, and categories 4 and 5, respectively) we observe that, similar to the mean values, the differences among the first four categories were clearly lower than the difference between categories 4 and 5.

In Figure 1B, the amplitude (the difference between the upper and lower limits of the category) of the different categories is also shown for the cities studied. The mean values obtained for the amplitude of the different categories were 3.9±1.9, 2.0±0.8, 2.7±1.0, 4.4±1.4, and 8.3±3.2, and categories 2 and 3 presented the lowest amplitude values. This finding is in agreement with the fact that these two categories were present in almost all of the overlaps detected (see Table III). The high amplitude for category 5 is consistent with previous results and is indicative of a high variability in the sound levels of the streets in this category.

Considering the results presented in Figure 2, we observed that there was high sensibility and low non-specificity in almost all of the categories, indicating good stratification method runs. Figure 2 describes the following data:

- All the cities had an overall sensitivity that was higher than 70%, and except in two cases, the sensitivity values were always above 80%. If we analyze the sensitivity of the different categories, in only 14% of the categories, a value of 70% was not exceeded.

- Considering the mean sensitivity values of the different categories, Table III reveals that the fifth category had a value that exceeded 90%, and categories 1 and 4 exceeded 85% sensitivity, while only category 2 had a value lower than 70%. The overall mean sensitivity value was very close to 90%. Therefore, these results showed that the proportion of correctly classified data that referred to the number of points assigned to the category was generally very high.
- All the cities had an overall non-specificity lower than 10%, and except for 4 cities, the non-specificity was lower than 5%. Considering the non-specificity of the different categories, in only 9% of the categories, the value of this variable was higher than 10%.
- Considering the mean non-specificity of the different categories, the first and fifth categories had values lower than 5%, and the rest of categories had values lower than 10%. The overall mean non-specificity value was lower than 5%. Therefore, the results showed that the proportion of incorrectly classified data in a category with respect to the number of data not assigned to this category was very low.

As expected from the previous results, the prediction values (Figure 3) were quite high. Thus, in all the studied cities, the overall predictive value was higher than 75%, and two-thirds of the cities were above 85%. Independently considering the results per category, in 83% of the categories, the prediction values were over 70% and were over 80% in 63% of the categories.

Considering the mean values of the predictions (Table IV), it can be seen that the mean value was always higher than 70%, was higher than 80% in categories 1 and 4 and exceeded 90% in category 5. The overall average predictive value was close to 90%, indicating the great prediction capacity of the method.

Therefore, the prediction capacity of the method is very elevated and makes the procedure very suitable for further applications such as noise prediction, helping design environmental policy and so on.

4. CONCLUSIONS

An alternative concept to accessibility for use in transport planning, urban planning and environmental pollution management is analyzed: the concept of functionality.

Functionality is the basis of the *categorization method*. In this work, this method was tested in 27 cities with major differences in size, location, socio-economic status, climate, etc.

Using the results obtained for all of the studied cities, the application reliability of the concept of functionality (as the basis of the *categorization method*) and the viability of this method for analysis of other pollutants related to traffic were analyzed.

The major conclusions drawn from the presented results are as follows:

- Statistical inferential analysis confirmed the existence of significant differences between the sound levels of the different categories of the studied cities and the different combinations of category pairs. The study has thus shown that urban noise is, in fact, stratified and that an appropriate way to study this stratification is by using the functionality concept. The proposed method, whose categories are based on the concept of functionality, highlights the stratification of the urban noise of the studied cities.
- Based on the previous demonstrated stratification, we proved by using the ROC analysis that the *categorization method* had high sensitivity and prediction capacity and low non-specificity. Considering all the cities' results, the overall sensitivity and predictions capacity values were close to 90%, and the non-specificity was below 4%.

Given the reduced number of sampling points necessary for the categorization method and the high variability in the characteristics of the 27 cities studied, the existence of stratification of the values of the studied pollution and the high prediction capacity of the proposed methodology clearly indicate the possibility of using the functionality concept in urban planning and the management of environmental noise. Moreover, given the relationships between different urban pollutants and traffic, it seems clear that the functionality concept and proposed or similar methodologies could be applied to the analysis of other pollutants that are related to traffic. Thus, the functionality concept could be widely applicable in urban pollution monitoring, urban planning and the development of environmental policy.

Acknowledgements

This work was partially supported by the Spanish Ministerio de Educación y Ciencia (Project No. TRA2006-03115), the European Regional Development Fund (ERDF), *Junta de Extremadura* (Projects PRI06A271, PD10166 and GR10175), *Consejería de Economía, Comercio e Innovación* and the European Social Fund.

References

Albert DG, Liu L. The effect of buildings on acoustic pulse propagation in an urban environment. J Acoust Soc Am 2010; 127:1335-1346.

ANSI. Quantities and Procedures for Description and Measurement of Environmental Sound - Part 4: Noise Assessment and Prediction of Long-Term Community Response - Includes Errata (10/01/97). New York: Acoustical Society of America; 1996

Babisch W. Transportation noise and cardiovascular risk. Updated review and synthesis of epidemiological studies indicate that the evidence has increased. Noise Health 2006; 8:1-29.

Barrigón Morillas JM, Gómez Escobar V, Méndez Sierra JA, Vílchez-Gómez R, Vaquero JM, Trujillo Carmona J. A categorization method applied to the study of urban road traffic noise. J Acoust Soc Am 2005; 17:2844-2852.

Barrigón Morillas JM, Gómez Escobar V, Méndez Sierra JA, Vílchez-Gómez R, Carmona del Río FJ, Trujillo Carmona J. Analysis of the prediction capacity of a categorization method for urban noise assessment. Appl Acoust 2011; 72:760-771.

Belojevic G, Jakovljevic G, Stojanov V, Paunovic K, Ilic J. Urban road-traffic noise and blood pressure and heart rate in preschool children. Environ Int 2008; 34:226-231.

Bowker GE, Baldauf R, Isakov V, Khlystov A, Petersen W. The effects of roadside structures on the transport and dispersion of ultrafine particles from highways. Atmos Environ 2007; 41:8128-8139.

Can A, Dekoninck L, Rademaker M, Van Renterghem T, De Baets B, Botteldooren D. Noise measurements as proxies for traffic parameters in monitoring networks. Sci Total Environ 2011a; 410-411:198-204.

Can A, Rademaker M, Van Renterghem T, Mishra V, Van Poppel M, Touhafi A, Theunis J, Botteldooren D. Correlation analysis of noise and ultrafine particle counts in a street canyon. Sci Total Environ 2011b; 409:564-572.

Chen H, Namdeo A, Bell MC. Classification of road traffic and roadside pollution concentrations for assessment of personal exposure. Environ Model Soft 2008;23:282–7.

COM. Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise - Declaration by the Commission in the Conciliation Committee on the Directive relating to the assessment and management of environmental noise (END). Brussels: The European parliament and the Council of the European Union, Official Journal L 189:12-26; 2002.

Di G, Liu X, Lin Q, Zheng Y, He L. The relationship between urban combined traffic noise and annoyance: An investigation in Dalian, north of China. Sci Total Environ 2012; 432:189-194.

EEA (European Environment Agency). Transport at a crossroads. TERM 2008: indicators tracking transport and environment in the European. Copenhagen: EEA; 2009.

EPA (Environmental Protection Agency). Our built and natural environments: a technical review of the interactions between land use, transportation, and environmental quality. Washington DC: EPA 231-R-01-002; 2001.

Fawcett T. An introduction to ROC analysis. Pattern Recogn Lett 2006; 27:861-874.

Foraster M, Deltell A, Basagaña X, Medina-Ramón M, Aguilera I, Bouso L, Grau M, Künzli N. Local determinants of road traffic noise levels versus determinants of air pollution levels in a Mediterranean city. Environ Res 2011; 111:177-183.

Freitas E, Mendonça C, Santos JA, Murteira C, Ferreira JP. Traffic noise abatement: How different pavements, vehicle speeds and traffic densities affect annoyance levels. Transport Res D-Tr E 2012; 17:321-326.

Geurs KT, van Wee B. Accessibility evaluation of land-use and transport strategies: Review and research directions. J Transp Geography 2004; 12:127-140.

Guedes ICM, Bertoli SR, Zannin PHT. Influence of urban shapes on environmental noise: A case study in Aracaju - Brazil. Sci Total Environ 2011; 412-413:66-76.

Halonen JI, Vahtera J, Stansfeld S, Yli-Toumi T, Salo P, Pentty J, Kivimäki M, Lanki T. Associations between nighttime traffic noise and sleep: The Finnish public sector study. Environ Health Perspect 2012; 120:1391-1396.

Hand DJ, Till RJ. A simple generalisation of the area under the ROC curve for multiple class classification problems. Mach Learn 2001; 45:171-186.

Holm S. A simple sequentially rejective multiple test procedure. Scand J Statist 1979; 6:65-70.

INE (Instituto Nacional de Estadística). Padrón municipal: cifras oficiales de población, España. Madrid: Instituto Nacional de Estadística; 2008.

INE (Instituto Nacional de Estadística). Padrón municipal: cifras oficiales de población, España. Madrid: Instituto Nacional de Estadística; 2010.

Iosub I, Iosub S, Grigorie V, Meghea A. Noise pollution and health impact in urban Arges area. Environ Eng Manage J 2009; 8: 855-858.

ISO 1996-2: 2007. Description, measurement and assessment of environmental noise. Part 2: Determination of environmental noise levels. Switzerland: International Organization for Standardization; 2007.

Kruskal WH, Wallis WA. Use of ranks in one-criterion variance analysis. J Am Stat Assoc 1952; 47:583-621.

Mann HB, Whitney DR. On a test of whether one of two random variables is stochastically larger than the other. Ann Math Stat 1947; 18:50-60.

OECD (Organization for Economic Cooperation and Development). Fighting noise in 1990s. Paris: OECD Publications; 1991.

Pathak V, Tripathi, BD, Mishra VK. Evaluation of traffic noise pollution and attitudes of exposed individuals in working place. Atmos Environ 2008; 42:3892-3898.

Paunović K, Jakovljević B, Belojević G. Predictors of noise annoyance in noisy and quiet urban streets. Sci Total Environ 2009; 407:3707-3711.

Rey Gozalo G, Barrigón Morillas JM, Gómez Escobar V. Analysis of noise exposure in two small towns. Acta Acustic 2012; 98:884-893.

Romeu J, Jiménez S, Genescà M, Pàmies T, Capdevilla R. Spatial sampling for night levels estimation in urban environments. J. Acoust. Soc. Am. 2006; 120:791-800.

Salomons EM, Berghauser Pont M. Urban traffic noise and the relation to urban density, form, and traffic elasticity. Landscape Urban Plan 2012; 108:2-16.

Sheng N, Wa Tang U. Spatial analysis of urban form and pedestrian exposure to traffic noise. Int J Environ R Public Heal 2011; 8:1977-1990.

Su JG, Brauer M, Buzzelli M. Estimating urban morphometry at the neighborhood scale for improvement in modeling long-term average air pollution concentrations. Atmos Environ 2008; 42:7884-7893.

Szeremeta B, Zannin PHT. Analysis and evaluation of soundscapes in public parks trough interviews and measurement of noise. Sci Total Environ 2009; 407:6143-6149.

Torrija AJ, Ruiz DP. Using recorded sound spectra profile as input data for real-time short-term urban road-traffic-flow estimation. Sci Total Environ 2012; 435-436: 270-279.

Vlahogianni EI, Golias JC, Ziomas IC. Traffic flow evolution effects to nitrogen dioxides predictability in large metropolitan areas. Transp Res D 2011;16:273–80.

Wang B, Kang J. Effects of urban morphology on the traffic noise distribution through noise mapping: A comparative study between UK and China. Appl Acoust 2011; 72:556-568.

WHO (World Health Organization). Guidelines for Community Noise. Geneva; WHO; 1999.

WHO (World Health Organization). Burden of disease from environmental noise. Quantification of healthy life years los in Europe. Geneva: WHO and JCR; 2011.

Wilcoxon F. Individual comparisons by ranking methods. Biometrics B 1945; 1:80-83.

TABLE I. Data for the studied cities.

City	Population (inhabitant number)	Area (km^2)	Density (inhabitants/km^2)
La Coronada	2,238	0.57	3,926
Arroyo de la Luz	6,477	1.17	5,536
Castuera	6,652	1.38	4,820
Guareña	7,365	1.27	5,799
Campo Maior (Portugal)	8,387	1.30	6,452
Azuaga	8,501	1.88	4,522
Trujillo	9,766	4.06	2,405
Miajadas	10,241	2.97	3,448
Olivenza	11,814	2.07	5,707
Coria	12,868	1.10	11,698
Zafra	16,218	2.12	7,650
Navalmoral de la Mata	17,103	1.99	8,594
Villanueva de la Serena	25,576	3.43	7,457
Almendralejo	33,177	6.03	5,502
Don Benito	34,540	6.97	4,956
Plasencia	40,105	9.63	4,165
Mérida	55,568	10.87	5,112
Talavera de la Reina	88,986	12.57	7,079
Cáceres	92,187	12.66	7,282
Valdivia (Chile)	129,952	33.00	3,938
Badajoz	146,832	17.20	8,537
Salamanca	155,740	18.05	8,628
Santander	181,589	15.60	11,640
Vitoria	221,270	30.00	7,376
Valladolid	318,461	37.02	8,602
Málaga	566,447	53.44	10,600
Sevilla	699,759	59.27	11,806

TABLE II. Mean value and standard deviation of L_{eq} (dBA) in the different categories for the studied cities.

City	Category 1	Category 2	Category 3	Category 4	Category 5
La Coronada	69.8±3.3	65.4±1.7	65.3±1.3	59.1±1.3	55.3±2.6
Arroyo de la Luz	65.7±1.1	-	62.1±1.2	60.6±0.9	55.9±2.3
Castuera	68.5±1.6	64.5±1.6	63.0±0.9	58.6±2.1	52.3±2.8
Guareña	67.5±2.3	65.9±2.0	63.8±1.2	60.8±1.3	56.2±2.2
Campo Maior	68.4±1.5	67.4±0.5	64.5±1.5	60.3±1.4	54.6±3.2
Azuaga	70.7±1.8	66.5±0.8	64.2±1.4	60.6±1.2	57.5±1.8
Trujillo	71.6±0.3	70.8±0.6	67.6±2.8	61.2±3.5	54.0±4.4
Miajadas	71.5±1.6	69.0±1.4	67.1±2.1	64.3±1.9	59.9±3.3
Olivenza	70.2±1.5	67.4±2.0	64.4±2.0	61.0±1.8	56.6±1.7
Coria	68.0±1.7	-	64.8±1.6	61.1±1.7	54.1±3.4
Zafra	70.7±1.5	66.7±0.7	65.5±2.2	60.8±1.4	55.6±2.4
Navalmoral de la Mata	70.5±1.1	66.4±1.2	65.0±2.4	61.3±3.4	55.0±2.1
Villanueva de la Serena	70.2±2.2	69.8±2.0	66.4±1.4	63.2±1.9	57.0±3.9
Almendralejo	73.6±0.7	70.6±2.2	68.7±1.3	65.3±1.7	57.5±3.5
Don Benito	71.0±1.6	68.8±1.3	65.9±1.2	64.0±2.1	59.5±2.3
Plasencia	71.5±0.8	69.5±0.8	67.1±1.5	64.7±1.3	59.7±3.2
Mérida	71.2±1.9	70.3±2.4	66.8±1.6	62.8±3.1	59.0±1.6
Talavera de la Reina	72.4±1.0	71.3±0.8	68.7±4.0	65.5±2.2	60.7±3.6
Cáceres	70.9±1.8	69.6±1.7	68.0±1.5	64.6±0.7	59.1±2.7
Valdivia	75.0±0.7	72.9±1.0	71.6±1.1	66.5±2.3	55.9±2.9
Badajoz	73.4±1.2	71.5±1.5	68.0±1.5	65.9±2.3	57.5±4.4
Salamanca	75.0±2.0	72.2±2.5	70.9±1.4	67.8±2.3	60.6±5.1
Santander	76.9±4.1	74.5±1.7	72.2±0.9	68.8±1.4	65.5±1.9
Vitoria	74.8±1.7	71.4±1.6	70.7±1.7	68.7±1.5	63.1±3.0
Valladolid	75.3±1.7	72.5±1.7	71.4±1.2	68.3±1.4	60.6±2.5
Málaga	76.9±2.2	74.7±0.9	72.5±1.1	71.1±1.4	62.6±2.8
Sevilla	76.5±1.2	73.7±1.4	72.2±1.1	67.8±1.5	61.9±2.8

TABLE III. Results of the Mann-Whitney U-test applied to pairs of categories. (*), (**), (***) indicate the grade of significance of the differences ($p \leq 0.05$, $p \leq 0.01$, and $p \leq 0.001$, respectively). (n.s.) indicates a non-significant difference ($p > 0.05$).

City	Category pairs									
	1-2	1-3	1-4	1-5	2-3	2-4	2-5	3-4	3-5	4-5
La Coronada	$6.3 \cdot 10^{-2}$ (n.s.)	$1.1 \cdot 10^{-2}$ (*)	$1.1 \cdot 10^{-2}$ (*)	$1.1 \cdot 10^{-2}$ (*)	$9.5 \cdot 10^{-1}$ (n.s.)	$8.0 \cdot 10^{-3}$ (**)	$8.0 \cdot 10^{-3}$ (**)	$2.2 \cdot 10^{-4}$ (***)	$2.2 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-2}$ (*)
A. de la Luz	-	$6.2 \cdot 10^{-4}$ (***)	$4.7 \cdot 10^{-4}$ (***)	$2.7 \cdot 10^{-4}$ (***)	-	-	-	$7.0 \cdot 10^{-4}$ (***)	$2.7 \cdot 10^{-4}$ (***)	$2.7 \cdot 10^{-4}$ (***)
Castuera	$1.0 \cdot 10^{-2}$ (*)	$1.0 \cdot 10^{-2}$ (*)	$1.0 \cdot 10^{-2}$ (*)	$1.0 \cdot 10^{-2}$ (*)	$1.2 \cdot 10^{-2}$ (*)	$1.7 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$2.6 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$1.7 \cdot 10^{-4}$ (***)
Guareña	$3.5 \cdot 10^{-1}$ (n.s.)	$4.3 \cdot 10^{-2}$ (*)	$2.2 \cdot 10^{-2}$ (*)	$2.2 \cdot 10^{-2}$ (*)	$1.3 \cdot 10^{-1}$ (n.s.)	$4.3 \cdot 10^{-2}$ (*)	$4.3 \cdot 10^{-2}$ (*)	$2.2 \cdot 10^{-2}$ (*)	$2.2 \cdot 10^{-2}$ (*)	$2.2 \cdot 10^{-2}$ (*)
Campo Maior	$1.1 \cdot 10^{-1}$ (n.s.)	$9.1 \cdot 10^{-4}$ (***)	$3.7 \cdot 10^{-4}$ (***)	$3.7 \cdot 10^{-4}$ (***)	$9.1 \cdot 10^{-4}$ (***)	$1.0 \cdot 10^{-3}$ (**)	$1.0 \cdot 10^{-3}$ (**)	$1.9 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$4.5 \cdot 10^{-4}$ (***)
Azuaga	$1.9 \cdot 10^{-3}$ (**)	$1.9 \cdot 10^{-3}$ (**)	$1.0 \cdot 10^{-3}$ (**)	$1.0 \cdot 10^{-3}$ (**)	$1.9 \cdot 10^{-3}$ (**)	$1.0 \cdot 10^{-3}$ (**)	$1.0 \cdot 10^{-3}$ (**)	$1.2 \cdot 10^{-3}$ (**)	$1.1 \cdot 10^{-3}$ (**)	$1.9 \cdot 10^{-3}$ (**)
Trujillo	$1.1 \cdot 10^{-1}$ (n.s.)	$9.6 \cdot 10^{-2}$ (n.s.)	$1.8 \cdot 10^{-2}$ (*)	$1.8 \cdot 10^{-2}$ (*)	$1.1 \cdot 10^{-1}$ (n.s.)	$1.8 \cdot 10^{-2}$ (*)	$1.8 \cdot 10^{-2}$ (*)	$9.6 \cdot 10^{-2}$ (n.s.)	$1.8 \cdot 10^{-2}$ (*)	$4.9 \cdot 10^{-3}$ (**)
Miajadas	$1.9 \cdot 10^{-2}$ (*)	$2.2 \cdot 10^{-3}$ (**)	$4.6 \cdot 10^{-4}$ (***)	$4.6 \cdot 10^{-4}$ (***)	$5.4 \cdot 10^{-2}$ (n.s.)	$2.2 \cdot 10^{-3}$ (**)	$8.2 \cdot 10^{-4}$ (***)	$9.2 \cdot 10^{-3}$ (**)	$2.2 \cdot 10^{-3}$ (**)	$8.4 \cdot 10^{-3}$ (**)
Olivenza	$3.2 \cdot 10^{-3}$ (**)	$2.2 \cdot 10^{-4}$ (***)	$2.2 \cdot 10^{-4}$ (***)	$2.2 \cdot 10^{-4}$ (***)	$3.1 \cdot 10^{-2}$ (*)	$1.5 \cdot 10^{-3}$ (**)	$1.5 \cdot 10^{-3}$ (**)	$2.2 \cdot 10^{-3}$ (**)	$2.2 \cdot 10^{-4}$ (***)	$1.5 \cdot 10^{-3}$ (**)
Coria	-	$8.0 \cdot 10^{-3}$ (**)	$2.3 \cdot 10^{-4}$ (***)	$2.3 \cdot 10^{-4}$ (***)	-	-	-	$7.5 \cdot 10^{-4}$ (***)	$7.5 \cdot 10^{-4}$ (***)	$1.3 \cdot 10^{-4}$ (***)
Zafra	$1.1 \cdot 10^{-4}$ (***)	$2.6 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$2.9 \cdot 10^{-2}$ (*)	$1.1 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)
N. de la Mata	$3.3 \cdot 10^{-3}$ (**)	$3.3 \cdot 10^{-3}$ (**)	$1.8 \cdot 10^{-3}$ (**)	$1.8 \cdot 10^{-3}$ (**)	$2.3 \cdot 10^{-1}$ (n.s.)	$4.1 \cdot 10^{-3}$ (**)	$4.6 \cdot 10^{-4}$ (***)	$5.3 \cdot 10^{-2}$ (n.s.)	$4.6 \cdot 10^{-4}$ (***)	$1.7 \cdot 10^{-3}$ (**)
V. de la Serena	$8.0 \cdot 10^{-1}$ (n.s.)	$1.0 \cdot 10^{-3}$ (**)	$1.5 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$2.9 \cdot 10^{-3}$ (**)	$2.6 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$1.7 \cdot 10^{-3}$ (**)	$1.1 \cdot 10^{-4}$ (***)	$2.9 \cdot 10^{-3}$ (**)
Almendralejo	$5.9 \cdot 10^{-3}$ (**)	$3.7 \cdot 10^{-4}$ (***)	$3.7 \cdot 10^{-4}$ (***)	$3.7 \cdot 10^{-4}$ (***)	$2.1 \cdot 10^{-2}$ (*)	$9.6 \cdot 10^{-4}$ (***)	$3.7 \cdot 10^{-4}$ (***)	$8.2 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)
Don Benito	$1.0 \cdot 10^{-2}$ (*)	$1.1 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$8.2 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$1.2 \cdot 10^{-2}$ (*)	$1.1 \cdot 10^{-4}$ (***)	$9.7 \cdot 10^{-4}$ (***)
Plasencia	$1.7 \cdot 10^{-3}$ (**)	$1.1 \cdot 10^{-4}$ (***)	$1.7 \cdot 10^{-4}$ (***)	$1.7 \cdot 10^{-4}$ (***)	$3.0 \cdot 10^{-3}$ (**)	$2.3 \cdot 10^{-4}$ (***)	$2.3 \cdot 10^{-4}$ (***)	$3.0 \cdot 10^{-3}$ (**)	$5.7 \cdot 10^{-5}$ (***)	$1.7 \cdot 10^{-4}$ (***)
Mérida	$5.4 \cdot 10^{-1}$ (n.s.)	$2.1 \cdot 10^{-3}$ (**)	$1.2 \cdot 10^{-4}$ (***)	$7.2 \cdot 10^{-4}$ (***)	$6.3 \cdot 10^{-3}$ (**)	$6.1 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$6.3 \cdot 10^{-3}$ (**)	$1.1 \cdot 10^{-4}$ (***)	$6.0 \cdot 10^{-3}$ (**)
T. de la Reina	$4.3 \cdot 10^{-2}$ (*)	$1.1 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$3.0 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$3.2 \cdot 10^{-3}$ (**)	$1.1 \cdot 10^{-4}$ (***)	$3.2 \cdot 10^{-3}$ (**)
Cáceres	$3.2 \cdot 10^{-1}$ (n.s.)	$3.2 \cdot 10^{-3}$ (**)	$1.1 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$5.8 \cdot 10^{-2}$ (n.s.)	$1.1 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)
Valdivia	$1.2 \cdot 10^{-3}$ (**)	$2.2 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$1.4 \cdot 10^{-2}$ (*)	$7.3 \cdot 10^{-4}$ (***)	$7.3 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)
Badajoz	$1.8 \cdot 10^{-2}$ (*)	$1.1 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$1.5 \cdot 10^{-3}$ (**)	$5.2 \cdot 10^{-4}$ (***)	$1.1 \cdot 10^{-4}$ (***)	$1.8 \cdot 10^{-2}$ (*)	$1.1 \cdot 10^{-4}$ (***)	$3.8 \cdot 10^{-4}$ (***)

Salamanca	$1.8\cdot10^{-2}$ (*)	$6.5\cdot10^{-4}$ (***)	$1.1\cdot10^{-4}$ (***)	$1.1\cdot10^{-4}$ (***)	$8.9\cdot10^{-2}$ (n.s.)	$1.3\cdot10^{-3}$ (**)	$1.1\cdot10^{-4}$ (***)	$4.5\cdot10^{-3}$ (**)	$1.1\cdot10^{-4}$ (***)	$2.6\cdot10^{-4}$ (***)
Santander	$1.9\cdot10^{-1}$ (n.s.)	$9.2\cdot10^{-3}$ (**)	$6.2\cdot10^{-4}$ (***)	$6.2\cdot10^{-4}$ (***)	$6.2\cdot10^{-3}$ (**)	$1.1\cdot10^{-4}$ (***)	$1.1\cdot10^{-4}$ (***)	$1.5\cdot10^{-4}$ (***)	$1.1\cdot10^{-4}$ (***)	$2.9\cdot10^{-3}$ (**)
Vitoria	$7.6\cdot10^{-4}$ (***)	$3.3\cdot10^{-4}$ (***)	$3.3\cdot10^{-4}$ (***)	$1.9\cdot10^{-4}$ (***)	$4.5\cdot10^{-1}$ (n.s.)	$1.2\cdot10^{-2}$ (*)	$1.1\cdot10^{-4}$ (***)	$2.1\cdot10^{-2}$ (*)	$3.3\cdot10^{-4}$ (***)	$1.7\cdot10^{-3}$ (**)
Valladolid	$1.5\cdot10^{-3}$ (**)	$1.1\cdot10^{-4}$ (***)	$1.1\cdot10^{-4}$ (***)	$1.1\cdot10^{-4}$ (***)	$1.4\cdot10^{-1}$ (n.s.)	$3.0\cdot10^{-4}$ (***)	$1.1\cdot10^{-4}$ (***)	$3.0\cdot10^{-4}$ (***)	$1.1\cdot10^{-4}$ (***)	$1.1\cdot10^{-4}$ (***)
Málaga	$4.1\cdot10^{-2}$ (*)	$1.7\cdot10^{-3}$ (**)	$3.7\cdot10^{-4}$ (***)	$2.6\cdot10^{-4}$ (***)	$2.6\cdot10^{-4}$ (***)	$1.1\cdot10^{-4}$ (***)	$1.1\cdot10^{-4}$ (***)	$4.1\cdot10^{-2}$ (*)	$1.1\cdot10^{-4}$ (***)	$1.1\cdot10^{-4}$ (***)
Sevilla	$1.3\cdot10^{-4}$ (***)	$1.1\cdot10^{-4}$ (***)	$1.1\cdot10^{-4}$ (***)	$1.1\cdot10^{-4}$ (***)	$1.9\cdot10^{-2}$ (*)	$1.1\cdot10^{-4}$ (***)	$1.1\cdot10^{-4}$ (***)	$1.1\cdot10^{-4}$ (***)	$1.1\cdot10^{-4}$ (***)	$1.3\cdot10^{-4}$ (***)

TABLE IV. Sensitivity (%), non-specificity (%) and predictive value (%) obtained from ROC analysis for the L_{eq} (dBA) mean values of the different categories and for the global L_{eq} value of the studied cities.

	Mean values (%)					
	Cat 1	**Cat 2**	**Cat 3**	**Cat 4**	**Cat 5**	**Global (weigthed)**
Sensitivity	87.2	66.6	74.6	85.5	93.6	89.4
No-specificity	3.9	6.3	6.0	5.3	2.1	3.3
Predictive value	84.4	70.1	76.8	82.5	93.6	89.3

FIGURE CAPTIONS

Figure 1**.** Mark (dBA) (A) and amplitude (dBA) (B) obtained from ROC analysis of the L_{eq} (dBA) values of the different categories of the studied cities.

Figure 2. Sensitivity (%) (A) and non-specificity (%) (B) obtained from ROC analysis of the L_{eq} (dBA) values of the different categories of the studied cities.

Figure 3. Predictive value (%) obtained from ROC analysis for the L_{eq} (dBA) values of the different categories and for the global L_{eq} value of the studied cities.

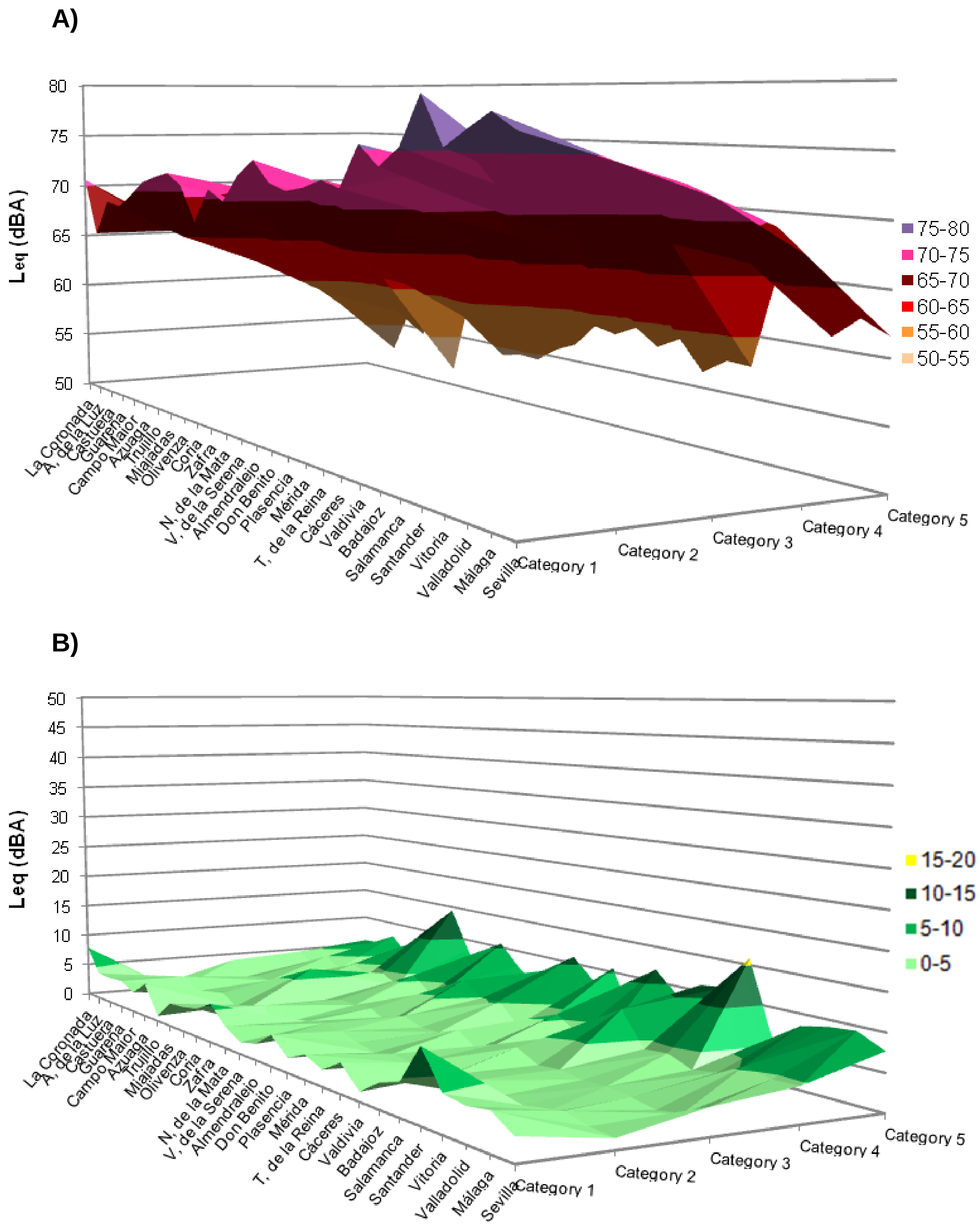
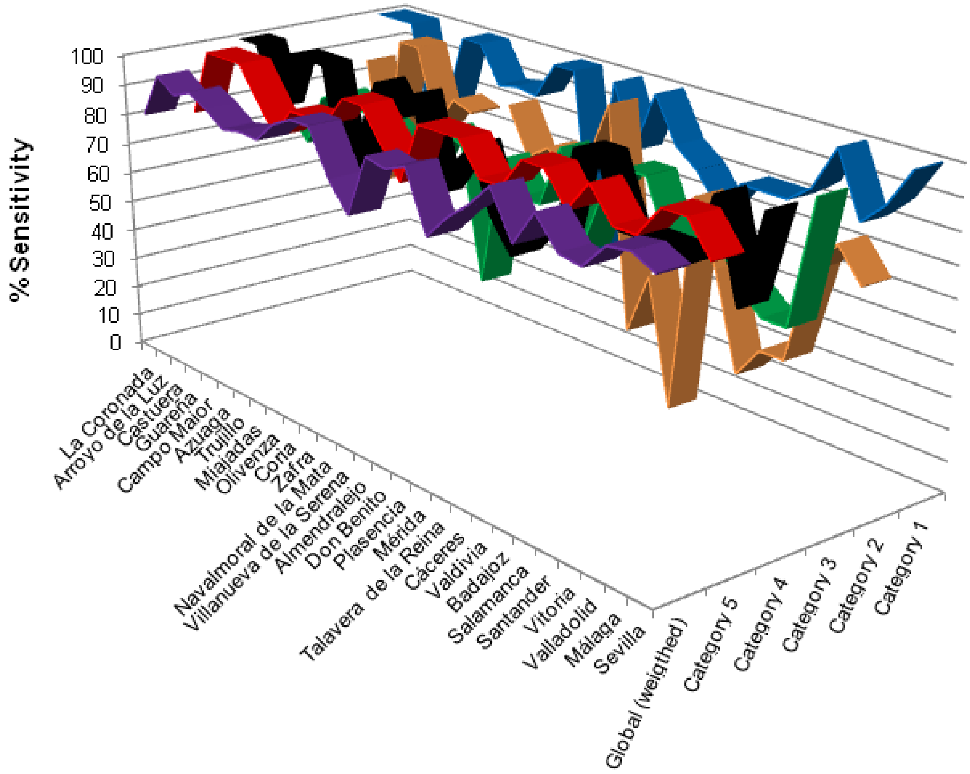

A)
Leq (dBA)
80
75
70
65
60
55
50
75-80
70-75
65-70
60-65
55-60
50-55
La Coronada
A. de la Luz
Castuera
Guareña
Campo Maior
Azuaga
Trujillo
Majadas
Olivenza
Coria
Zafra
N. de la Mata
V. de la Serena
Almendralejo
Don Benito
Plasencia
Mérida
T. de la Reina
Cáceres
Valdivia
Badajoz
Salamanca
Santander
Vitoria
Valladolid
Málaga
Sevilla
Category 1
Category 2
Category 3
Category 4
Category 5
B)
Leq (dBA)
50
45
40
35
30
25
20
15
10
5
0
15-20
10-15
5-10
0-5
La Coronada
A. de la Luz
Castuera
Guareña
Campo Maior
Azuaga
Trujillo
Majadas
Olivenza
Coria
Zafra
N. de la Mata
V. de la Serena
Almendralejo
Don Benito
Plasencia
Mérida
T. de la Reina
Cáceres
Valdivia
Badajoz
Salamanca
Santander
Vitoria
Valladolid
Málaga
Sevilla
Category 1
Category 2
Category 3
Category 4
Category 5

Figure 1

A)


% Sensitivity
100
90
80
70
60
50
40
30
20
10
0
La Coronada
Arroyo de la Luz
Castuera
Guareña
Campo Maior
Azuaga
Trujillo
Miajadas
Olivenza
Coria
Zafra
Navalmoral de la Mata
Villanueva de la Serena
Almendralejo
Don Benito
Plasencia
Mérida
Talavera de la Reina
Cáceres
Valdivia
Badajoz
Salamanca
Santander
Vitoria
Valladolid
Málaga
Sevilla
Global (weigthed)
Category 5
Category 4
Category 3
Category 2
Category 1

B)

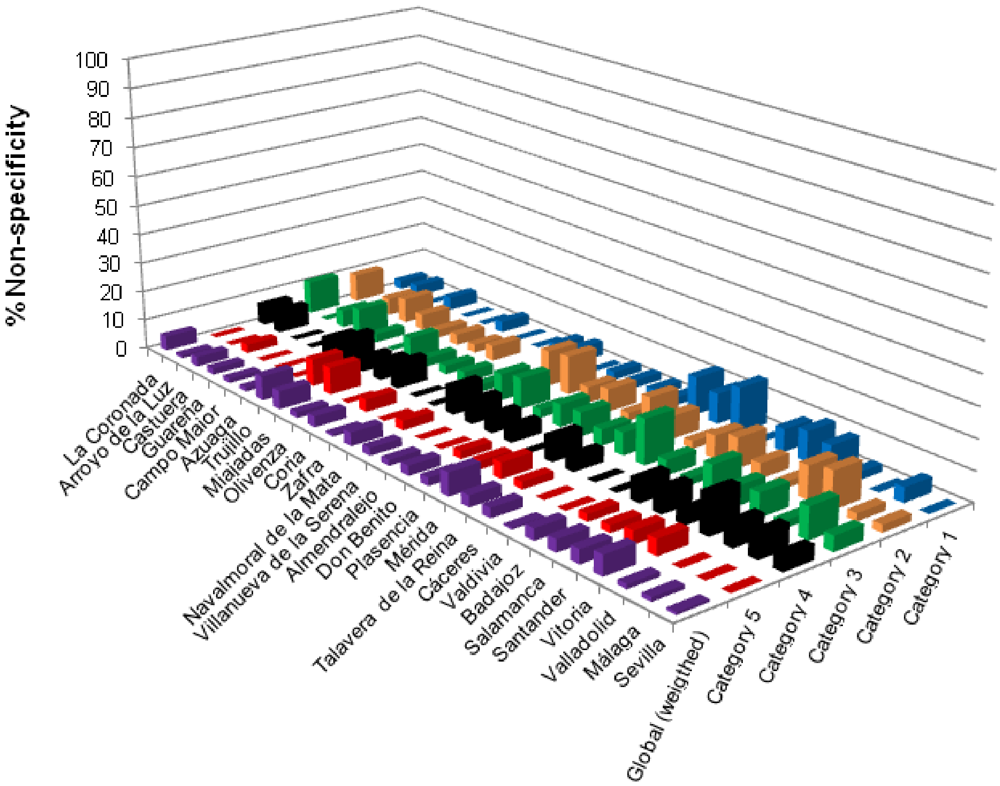

% Non-specificity
100
90
80
70
60
50
40
30
20
10
0
La Coronada
Arroyo de la Luz
Castuera
Guareña
Campo Maior
Azuaga
Trujillo
Miajadas
Olivenza
Coria
Zafra
Navalmoral de la Mata
Villanueva de la Serena
Almendralejo
Don Benito
Plasencia
Mérida
Talavera de la Reina
Cáceres
Valdivia
Badajoz
Salamanca
Santander
Vitoria
Valladolid
Málaga
Sevilla
Global (weigthed)
Category 5
Category 4
Category 3
Category 2
Category 1

Figure 2

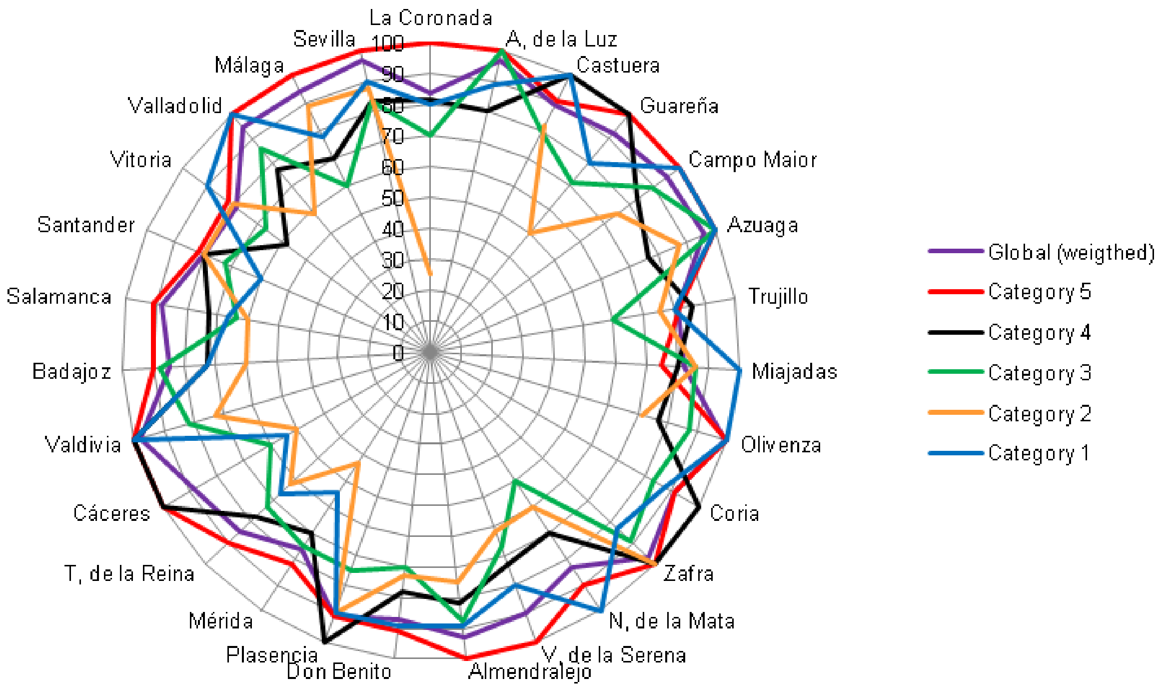

La Coronada
A, de la Luz
Castuera
Guareña
Campo Maior
Azuaga
Trujillo
Miajadas
Olivenza
Coria
Zafra
N, de la Mata
V, de la Serena
Almendralejo
Don Benito
Plasencia
Mérida
T, de la Reina
Cáceres
Valdivia
Badajoz
Salamanca
Santander
Vitoria
Valladolid
Málaga
Sevilla
100
90
80
70
60
50
40
30
20
10
0
Global (weigthed)
Category 5
Category 4
Category 3
Category 2
Category 1

Figure 3

KML File (for GoogleMaps)

Click here to download KML File (for GoogleMaps): Cities.kml