

# ACOUSTIC ENVIRONMENT AND URBAN SUSTAINABLE DEVELOPMENT IN THE CITY OF CÁCERES

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The city of Cáceres has a proportion of green area per capita higher than the recommended by the World Health Organization. In addition, this city has quiet areas with an important aesthetic value, as is the case of the Old Town. Urban green spaces mainly provide environmental benefits to the residents. The Old Town, besides its environmental value, has currently a clear economic importance. For this reason, in order to develop these areas in next years, projects which involve increasing the extension of some of these green spaces – Parque del Príncipe – and the connection of these areas with the Old Town through green ways – Paseo de Cánovas – have been approved. In this study the features of these areas were evaluated through the perception of passers-by. The results show how the acoustic environment is an important factor to be considered in the perception of these urban environments. Noise satisfaction had the highest significant correlation with respect to the overall satisfaction despite obtaining a lower satisfaction than the other features. Also, the low sound levels mostly coming from road traffic had a significant correlation with respect to noise satisfaction. Therefore, if the environmental noise, specially noise coming from road traffic, is not taken into account in the development of these projects perhaps some of the sustainable development objectives would be negatively influenced.

**Keywords:** urban green space, quiet area, acoustic environment, noise annoyance, urban planning.

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## 1. Introduction

In the coming years it is expected that resident population in cities will continue growing. This fact involves that cities have to continue their economic development without decreasing the quality of life of citizens or producing environmental degradation. European Commission has created indicators to measure progress towards sustainability [1]: Citizens' satisfaction with the local community, local mobility and passenger transportation, availability of local public green spaces and local services, quality of local outdoor air, noise pollution... Also, these indicators are included in web applications that are created to guide cities on their own path towards sustainability [2]. Current studies show that the presence of green spaces and quiet areas contributes to improve the health and quality of life of citizens [3-7].

The city of Cáceres (Spain) has included the sustainable urban development integrated into its strategic goals. This city has a proportion of green area per capita higher than the recommended by

the World Health Organization and preserves an important urban, architectural and cultural heritage (Old Town). However, urban planners identify the following problems [8]: urban mobility, social segregation, ageing and economic stagnation. For this reason, in order to combat these problems, a new environmental corridor will be created in the city of Cáceres. This project plans to increase the extension of the green space "Parque del Príncipe" and to connect this area with the Old Town through the green way "Paseo de Cánovas" [8]. Figure 1 shows the urban spaces that will be part of the environmental corridor.

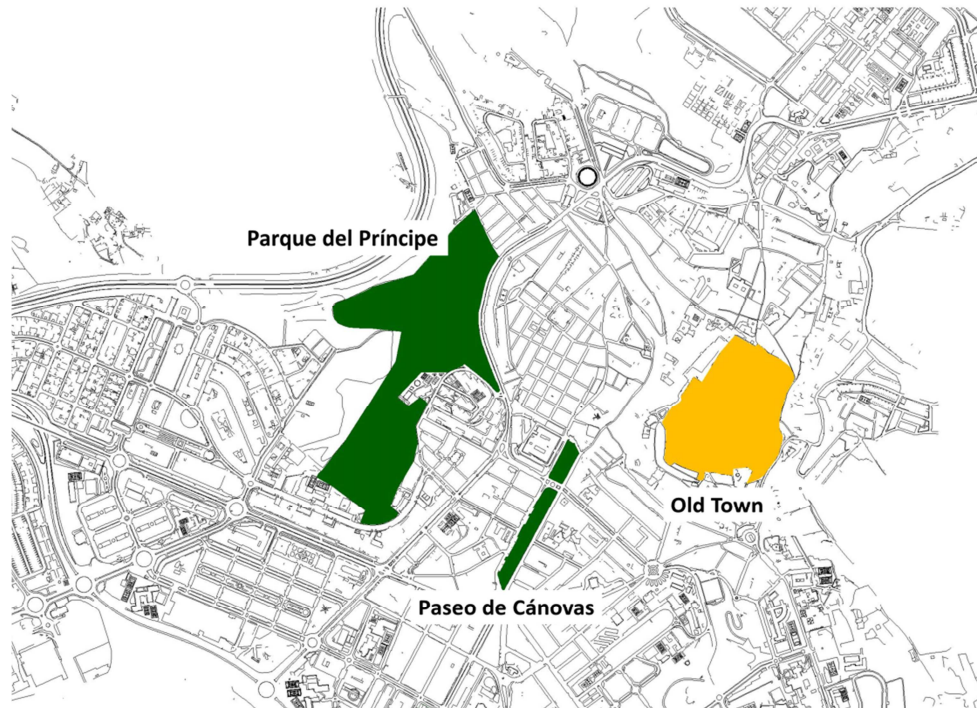


Figure 1: Urban spaces within the environmental corridor

The intervention in this area aims to connect the adjacent districts (Old Town, North, West and New West) through a high quality environment and to increase greatly the tourist attraction. In these districts the urban problems mentioned above are more evident.

However, this project does not include a priori acoustic aspects despite there is extensive information of acoustic studies carried out in different urban environments of Cáceres [9-16]. For this reason, the main objective of this study was to analyse the perception of the passers-by to the environmental features, including noise, of the areas "Parque del Príncipe", "Paseo de Cánovas" and Old Town and its relation with the overall perception. In this way, the results provide us information about the condition of these urban environments and about the importance of acting on some features in future projects to improve the overall perception. Also, in this study sound levels in different locations were sampled to analyse their relation with the noise perception of passers-by and their acoustic situation compared to other urban areas.

## 2. Methods

A survey was carried out to evaluate the perception of the passers-by to the features of the urban areas "Parque del Príncipe", "Paseo de Cánovas" and Old Town of Cáceres (Spain). Respondents were randomly selected and the survey length was 10 minutes approximately. A total of 122 surveys were carried out: 60 in the "Parque del Príncipe", 12 in the "Paseo de Cánovas" and 50 in the Old Town. This study analysed the dimension: the satisfaction with the features of urban area. This dimension was constituted by 12 features in green spaces surveys (cleanliness, air, noise, aesthetics, security, users, conservation, location, size, shadows, grove and overall) and by 7 items in the Old Town surveys (cleaning, air, noise, aesthetics, security, smell and overall). The 5-point Likert scale

ranging from 0 (not at all) to 4 (a lot) was used to evaluate the features. The internal consistency of reliability of test scores was analysed by Cronbach's alpha. Cronbach's alpha values were higher than 0.8.

Sound measurements were taken simultaneously with the surveys. The sound descriptor Leq (dBA) was measured with a sound-level meter (Brüel & Kjaer 2238) and with binaural recording device (Noise Book from Head Acoustics) following the ISO 1996–2 standard guidelines [17,18].

### 3. Results and Discussion

The results of Table 1 show that the Old Town has higher overall satisfaction than green spaces. 100% of passers-by of the Old Town have an overall satisfaction from 3 (quite) to 4 (a lot). Respondents are "quite" overall satisfied with the features of "Parque del Príncipe". However, "Paseo del Cánovas" has an overall average satisfaction of 2.6.

Table 1: Mean, median and percentage distribution of the level of satisfaction of passers-by to the features of "Parque del Príncipe", "Paseo de Cánovas" and Old Town of Cáceres.

Urban area	Feature	Level of satisfaction (Scale 0–4)						
		Mean	Median	% Respondents				
				0	1	2	3	4
Príncipe	Cleanliness	3.1	3	0.0	1.7	15.0	51.7	31.7
	Air	3.2	3	0.0	0.0	11.7	56.7	31.7
	Noise	2.8	3	0.0	0.0	36.7	50.0	13.3
	Aesthetic	3.7	4	0.0	1.7	0.0	30.0	68.3
	Security	3.3	3	0.0	1.7	10.0	50.0	38.3
	User	3.0	3	1.7	10.0	11.7	40.0	36.7
	Conservation	3.3	3	0.0	0.0	10.0	50.0	40.0
	Location	3.7	4	0.0	1.7	1.7	18.3	78.3
	Size	3.8	4	0.0	0.0	0.0	20.0	80.0
	Shadows	3.7	4	0.0	0.0	8.3	18.3	73.3
	Grove	3.7	4	0.0	0.0	5.0	20.0	75.0
	Overall	3.3	3	0.0	1.7	3.3	60.0	35.0
Cánovas	Cleanliness	2.8	3	0.0	0.0	33.3	50.0	16.7
	Air	1.5	1.5	0.0	50.0	50.0	0.0	0.0
	Noise	0.8	1	41.7	41.7	16.7	0.0	0.0
	Aesthetic	2.4	2	0.0	8.3	50.0	33.3	8.3
	Security	3.8	4	0.0	0.0	0.0	25.0	75.0
	User	2.8	3	8.3	8.3	16.7	33.3	33.3
	Conservation	3.1	3	0.0	0.0	8.3	75.0	16.7
	Location	3.8	4	0.0	0.0	0.0	25.0	75.0
	Size	2.9	3	0.0	0.0	25.0	58.3	16.7
	Shadows	2.6	3	0.0	0.0	41.7	58.3	0.0
	Grove	2.6	3	0.0	0.0	41.7	58.3	0.0
	Overall	2.6	2.5	0.0	8.3	41.7	33.3	16.7
Old Town	Cleanliness	3.1	3	0.0	0.0	14.0	62.0	24.0
	Air	3.3	3	0.0	0.0	2.0	68.0	30.0
	Noise	3.2	3	0.0	0.0	14.0	56.0	30.0
	Aesthetic	3.5	4	2.0	0.0	12.0	18.0	68.0
	Security	2.7	3	2.0	2.0	36.0	46.0	14.0
	Smell	3.0	3	0.0	4.0	24.0	40.0	32.0
	Overall	3.7	4	0.0	0.0	0.0	30.0	70.0

Regarding to the satisfaction of passers-by about the features, most of them have an average satisfaction higher than 2 (moderate). Even the average satisfaction exceeds the value of 3 for most of the features of "Parque del Príncipe" and Old Town. Therefore, the current situation in these areas does not present significant problems that involve an immediate action. Approximately 80% of the respondents present a lot of satisfaction with the location and size of "Parque del Príncipe". This involves that the median of the passers-by satisfaction is 4 for these two features. These two features were the main objectives of the future projects of the urban planners in the city of Cáceres.

The satisfaction of the features of "Parque del Príncipe" is higher than the obtained on "Paseo de Cánovas" (except for "security" and "location"). The greater extent of this green space and the lower influence of roads with a high flow of road traffic may be the reason of this difference. However, the Old Town and the "Parque del Príncipe" show high similarity in the satisfaction of the features except for "security" and "noise". Also, there are significant differences in the overall assessment between both urban areas.

In green spaces the feature with a lower average satisfaction is noise. 37% of the respondents in "Parque del Príncipe" and 100% in "Paseo de Cánovas" have a satisfaction of 0 (not at all) to 2 (moderate). "Paseo de Cánovas" is crossed by the main traffic roads whose function is to form connections with other Spanish towns and to interconnect those preferred streets (Category 1) and "Parque del Príncipe" is surrounded by streets that lead to regional roads and centers of interest in the town (Category 3) [9]. Categories 1 and 3 in Cáceres have a day-evening-night level of 71 dB and 63 dB approximately [9]. Therefore, these categories are called black and grey acoustic zones, respectively [13]. In addition, as shown in Table 2, the average noise satisfaction in green spaces has significant differences with respect to the other features. In most pairwise of features compared, this difference is stated for a 99.9% probability.

Road traffic in the Old Town is restricted. Perhaps, this is one of the reasons why in this zone the greatest satisfaction to noise is obtained and also noise does not present significant differences compared to the features "cleanliness", "air" and "smell" (see Table 2).

Table 2: *p*-Values of pairwise comparisons of features using Mann-Whitney *U* test.

Feature	Noise (Príncipe)	Noise (Cánovas)	Noise (Old Town)
Cleanliness	0.004	<0.001	0.630
Air	<0.001	0.023	0.392
Aesthetic	<0.001	<0.001	0.002
Security	<0.001	<0.001	0.002
User	0.027	<0.001	–
Conservation	<0.001	<0.001	–
Location	<0.001	<0.001	–
Size	<0.001	<0.001	–
Shadows	<0.001	<0.001	–
Grove	<0.001	<0.001	–
Smell	–	–	0.440

Next, the relation between the satisfaction of the different features with respect to the overall satisfaction for each urban area was analysed. Results are shown in table 2.

Table 2: Bivariate correlation (Kendall's tau-b) between features and overall satisfaction of urban areas of Cáceres.

Correlation coefficient	Overall (Príncipe)	Overall (Cánovas)	Overall (Old Town)
Cleanliness	0.44 <sup>***</sup>	0.56 <sup>*</sup>	0.37 <sup>**</sup>
Air	0.38 <sup>**</sup>	0.50 <sup>n.s.</sup>	0.30 <sup>*</sup>
Noise	0.41 <sup>**</sup>	0.77 <sup>**</sup>	0.41 <sup>**</sup>
Aesthetic	0.17 <sup>n.s.</sup>	0.75 <sup>**</sup>	0.37 <sup>**</sup>
Security	0.15 <sup>n.s.</sup>	-0.08 <sup>n.s.</sup>	0.40 <sup>**</sup>
User	0.11 <sup>n.s.</sup>	0.04 <sup>n.s.</sup>	—
Conservation	0.43 <sup>***</sup>	0.37 <sup>n.s.</sup>	—
Location	-0.01 <sup>n.s.</sup>	0.33 <sup>n.s.</sup>	—
Size	0.24 <sup>n.s.</sup>	0.65 <sup>*</sup>	—
Shadows	0.17 <sup>n.s.</sup>	0.5 <sup>n.s.</sup>	—
Grove	0.10 <sup>n.s.</sup>	0.53 <sup>n.s.</sup>	—
Smell	—	—	0.37 <sup>**</sup>
<sup>*</sup> Significant at $p \leq 0.05$ ; <sup>**</sup> Significant at $p \leq 0.01$ ; <sup>***</sup> Significant at $p \leq 0.001$ ; <sup>n.s.</sup> Non-significant difference ( $p > 0.05$ )			

Noise satisfaction is one of the features worse evaluated in the urban areas studied, but it is also one of the features with a higher correlation coefficient with respect to the overall assessment. Therefore, noise is a feature that should be considered by urban planners to improve the overall satisfaction of passers-by.

In Table 2, the bivariate relation between noise and the rest of the features were analysed. However, a partial correlation analysis was performed because some features have similarities in the distribution of their values (see Table 1) and perhaps, as Figure 2 shows, respondents might be associating some features.

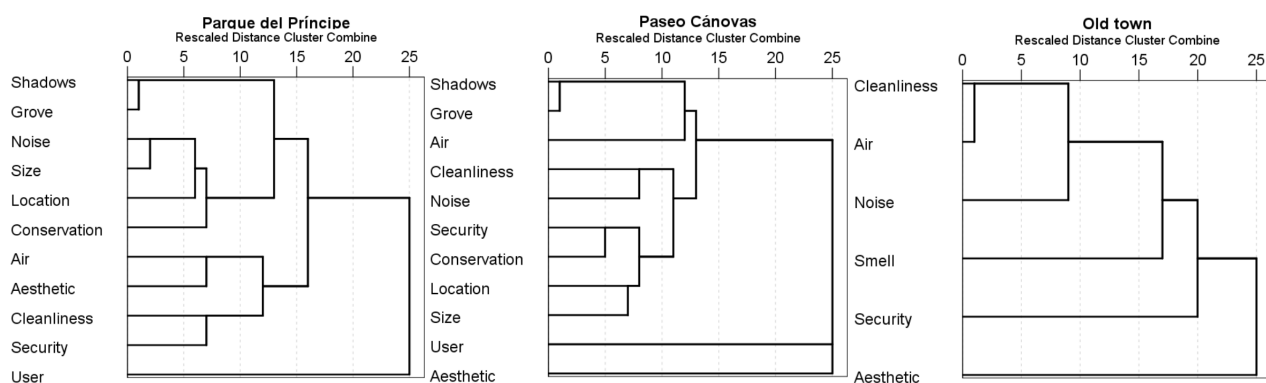


Figure 2: Dendrograms using Ward Linkage

The Kendall's tau-b test was used to analyse the correlation between pairwise of variables, removing the possible effects of the other variables of the dimension. This analysis could not be performed in "Paseo de Cánovas" because of the shortage of data. The results of the partial correlation analysis showed that in "Parque del Príncipe" only the features "noise" and "conservation" had a significant relation with respect to the overall assessment. The correlation coefficients were 0.25<sup>\*\*</sup>



for both features. In the "Parque del Príncipe" dendrogram (see Figure 2), for a cluster distance lower than 15, "noise" and "conservation" belong to two independent clusters. Perhaps this is the reason why "cleanliness" and "air" features, which are in the same cluster as "noise", lose their significance in a partial correlation analysis.

The results of the partial correlation analysis in the Old Town showed that "noise" and "aesthetics" are the only two features that maintain their significant relation with overall satisfaction. The correlation coefficients were  $0.36^{***}$  and  $0.30^{**}$  respectively. "Cleanliness", "air", "safety" and "smell" features lose meaning in their possible relation with "noise", as shown by the dendrogram of the Old Town (see Figure 2).

The "Paseo de Cánovas" dendrogram shows the feature "noise" in a separate cluster. This feature, as shown in Table 2, has the highest coefficient of bivariate correlation with respect to overall satisfaction. Therefore, if a partial correlation could have been made, would be expected that noise had had the highest partial correlation coefficient.

The results obtained in the partial correlation analysis corroborate the conclusions obtained previously: noise is a feature that influences significantly in the overall satisfaction.

Also in this study, as mentioned in the methodology, sound levels were registered at the same time as surveys. The main sound source was road traffic. Figure 3 (a) shows how the average sound levels registered in "Paseo de Cánovas" are similar to those registered in main roads [9,20]. However, sound levels registered in "Parque del Príncipe" and in the Old Town are lower than those of "Paseo de Cánovas". Sound levels registered in "Parque del Príncipe" are similar to those registered in neighbourhood streets of Cáceres (Category 5) [9] and the registered in the Old Town are similar to those registered on neighbourhood streets of small towns [21,22].

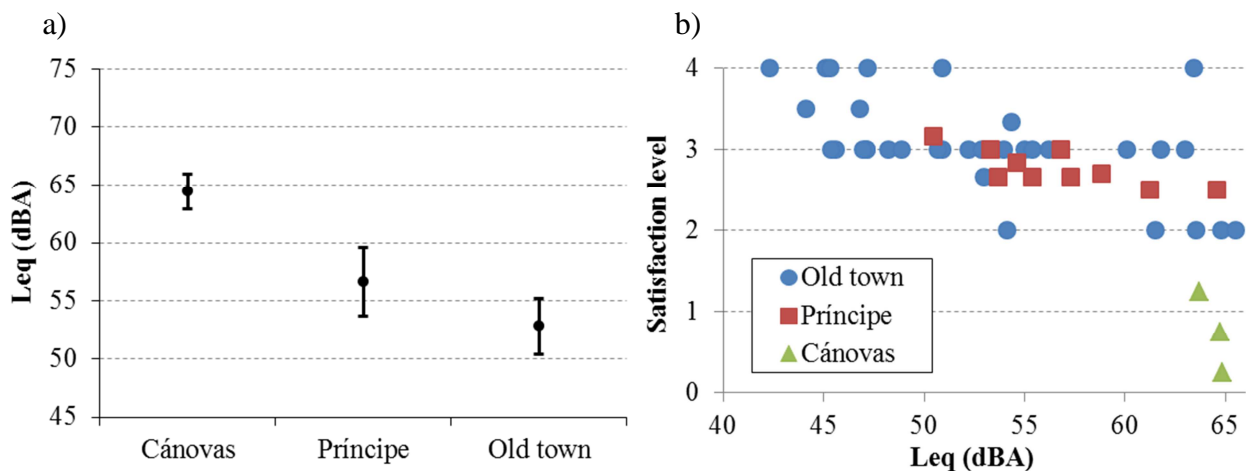


Figure 3: Average equivalent sound level (a) and its relation to noise satisfaction of passers-by (b).

In spite of the low sound values registered in "Parque del Príncipe" and in the Old Town, these were correlated to the level of noise satisfaction as shown in Figure 3 (b). The correlation coefficients (Spearman's rho) were  $-0.62^{***}$  and  $-0.82^{**}$ . Therefore, the equivalent sound level, as in previous studies [23], showed a significant correlation with noise perception of the respondents.

Future corrective measurements on road traffic in these urban areas that should imply a reduction of noise levels will be a benefit in the satisfaction of passers-by to noise of these areas and, in turn, a benefit in the satisfaction of these urban areas.

## 4. Conclusions

This study carried out in the green spaces of "Parque del Príncipe" and "Paseo de Cánovas" and in the Old Town of the city of Cáceres showed that passers-by give to noise the lowest satisfaction compared to other features in spite of this noise satisfaction proved to have the highest correlation coefficient significant with respect to overall satisfaction. For this reason, the new management and urban development plans of these areas must consider the noise and, above all, the noise coming from traffic road. Low values of the equivalent sound level registered in "Parque del Príncipe" and in the Old Town, proceeding mostly from the road traffic, had a significant correlation with the level of satisfaction to the noise of the passers-by.

## Acknowledgements

The authors wish to thank the funded Project GR15063, Junta de Extremadura, Consejería de Economía e Infraestructuras and Fondo Europeo de Desarrollo Regional (FEDER). For the same reason, the first author also wishes to thank the the National Commission for Scientific and Technological Research (CONICYT) through Nacional Fund for Scientific and Technological Development (FONDECYT) for research initiation (No. 11140043).



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