

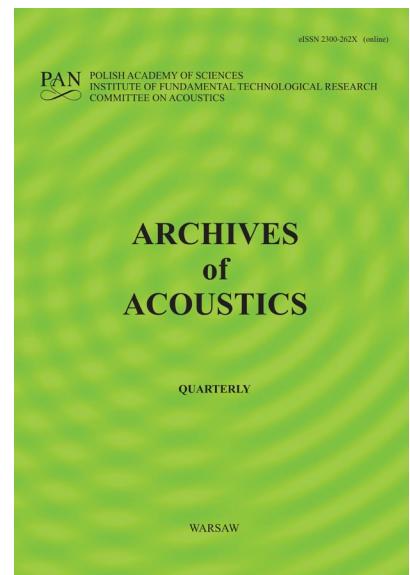
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**Title:** Application of ISO 12913 Standard to Assess Urban Soundscapes: A Case Study on Poznań

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**DOI:** <https://doi.org/10.24423/archacoust.2026.4337>

**Journal:** *Archives of Acoustics*

**ISSN:** 0137-5075, e-ISSN: 2300-262X

**Publication status:** In press

**Received:** 2025-09-17

**Revised:** 2026-01-20

**Accepted:** 2026-01-27

**Published pre-proof:** 2026-01-30

### Please cite this article as:

Dumanowski J., Preis A., Felcyn J. (2026), Application of ISO 12913 Standard to Assess Urban Soundscapes: A Case Study on Poznań, *Archives of Acoustics*, <https://doi.org/10.24423/archacoust.2026.4337>

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# APPLICATION OF ISO 12913 STANDARD TO ASSESS URBAN SOUNDSCAPES: A CASE STUDY ON POZNAŃ

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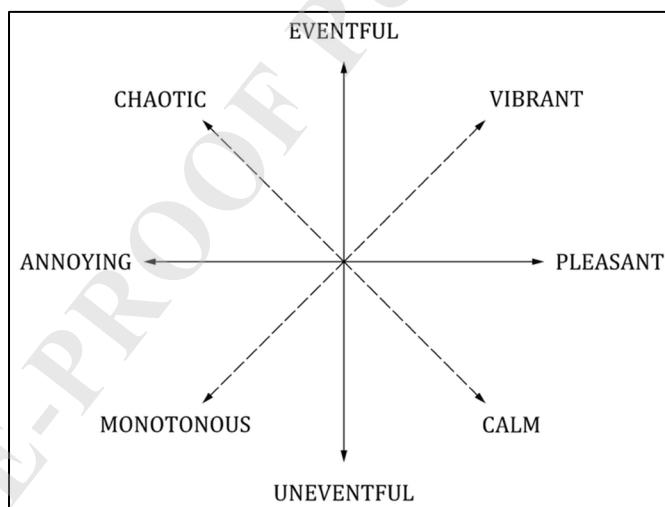
## Abstract

ISO 12913 standards provide a unified framework for describing and assessing soundscapes, yet the absence of a Polish translation has so far limited their practical use. This paper presents the first application of a validated Polish version of the ISO 12913-2 perceptual attributes, enabling full cross-language comparability of results. Whereas Polish research has traditionally focused on noise annoyance and broad judgements of acoustic comfort or discomfort, we outline the complete ISO-compliant assessment procedure, which combines: a soundwalk, questionnaires and audio-visual recording. The study was conducted at eight diverse urban locations in Poznań, Poland. Participants rated the soundscapes using eight attributes: *przyjemne, tętniące życiem, bogate w wydarzenia, chaotyczne, dokuczliwe, monotonne, ubogie w wydarzenia, spokojne*. Each rating set is mapped to a point in the two-dimensional pleasantness-eventfulness space defined in ISO 12913-3, facilitating visual comparison of locations and the identification of design needs. Results reveal pronounced perceptual differences between spatial typologies and demonstrate that the standardized approach provides richer, multidimensional information about the acoustic environment than conventional noise indicators. The proposed methodology establishes a reference framework for Polish soundscape studies and can support the creation of more people-friendly urban acoustic environments.

**Keywords:** soundscape, ISO 12913, Polish translation, soundwalk, perceptual attributes.

### 34 1. Introduction

35 The ISO 12913 standards provide a unified framework for describing and assessing  
 36 soundscapes. Part 1 (ISO, 2014) defines the concept of a “soundscape” and presents its  
 37 conceptual model. Part 2 (ISO, 2018) specifies the requirements for data collection and  
 38 reporting in soundscape studies, while Part 3 (ISO, 2025) sets out methods for analyzing and  
 39 interpreting those data. Method A in Part 2 is a valuable source for acquiring quantitative data  
 40 during soundwalks. The questionnaire permits a subjective evaluation of the perceived affective  
 41 quality of the acoustic environment using eight attributes - pleasant, vibrant, eventful, chaotic,  
 42 annoying, monotonous and calm - on a five-point bipolar Likert scale. These attributes are  
 43 embedded in the Soundscape Circumplex Model (Axelsson *et al.*, 2010; ISO, 2025). In the ideal  
 44 circumplex, adjacent attributes (i.e. pleasant-vibrant) are spaced 45 degrees apart, whereas  
 45 opposing ones (i.e. pleasant-annoying) are 180 degrees apart (Fig. 1). From these eight  
 46 attributes, the formulas in ISO/TS 12913-3 yield the indices Pleasantness and Eventfulness,  
 47 which are displayed in a two-dimensional Eventfulness-Pleasantness coordinate system (ISO,  
 48 2025; Mitchell *et al.*, 2022).



49  
 50 Fig. 1. Soundscape Circumplex Model adapted from Fig. A.1  
 51 of ISO/TS 12913-3:2025 (ISO, 2025).

52 The Soundscape Attributes Translation Project (SATP) demonstrated that equal angular  
 53 spacing between attributes is an idealized assumption and the angles depend strongly on the  
 54 language in which the acoustic environment is assessed (Aletta *et al.*, 2024). The project  
 55 developed a protocol for validating translations of the ISO 12913-2:2018 soundscape attributes,  
 56 consisting of a headphones-based listening experiment and a four-step validation method  
 57 employing various statistical analyses. Another outcome was the 2025 update of ISO/TS

58 12913-3, which now includes correction angles for 13 languages that successfully passed  
 59 validation, to be applied when calculating Pleasantness and Eventfulness. This update ensures  
 60 cross-lingual comparability of soundscape assessments.

61 Pleasantness ( $P_{ISO}$ ) and Eventfulness ( $E_{ISO}$ ) coordinates are calculated (Aletta *et al.*, 2024; ISO,  
 62 2025) using Equations 1 and 2:

$$P_{ISO} = \frac{1}{\lambda_P} \sum_{i=1}^8 \cos(\theta_i) \cdot \xi_i \quad (1)$$

$$E_{ISO} = \frac{1}{\lambda_E} \sum_{i=1}^8 \sin(\theta_i) \cdot \xi_i \quad (2)$$

63 where  $i$  indexes each circumplex scale,  $\theta_i$  is the adjusted angle for the  $i^{\text{th}}$  soundscape attribute,  
 64 and  $\xi_i$  is the value for that scale. The  $1/\lambda$  provides a scaling factor to bring the range of  $P_{ISO}$ ,  
 65  $E_{ISO}$  values to  $[-1, +1]$  (Eqs. 3 and 4):

$$\lambda_P = \frac{\rho}{2} \sum_{i=1}^8 |\cos \theta_i| \quad (3)$$

$$\lambda_E = \frac{\rho}{2} \sum_{i=1}^8 |\sin \theta_i| \quad (4)$$

66 where  $\rho$  is the range of the possible response values (i.e.,  $\rho = 5 - 1 = 4$  for the Likert scale,  
 67  $\rho = 100$  for 0-100 scale responses).

## 68 2. Polish version of soundscape attributes

69 Until now, Polish psychoacoustic research has usually assessed soundscapes differently - by  
 70 determining their annoyance, comfort or discomfort (Preis *et al.*, 2015; Szychowska *et al.*,  
 71 2018; Falcyn *et al.*, 2021). Although Polish studies using ISO 12913 exist (Mlynarczyk, Wiciak,  
 72 2024), the manner in which the individual attributes were translated in their questionnaires is  
 73 unclear. The absence of a Polish version of ISO 12913 created the need for a validated Polish  
 74 version of the soundscape attributes. Consequently, we contacted the SATP leadership to join  
 75 the project as researchers from Adam Mickiewicz University in Poznań. Through our  
 76 participation, we developed a validated Polish attribute set - *przyjemne, tętniące życiem, bogate*  
 77 *w wydarzenia, chaotyczne, dokuczliwe, monotonne, ubogie w wydarzenia, spokojne*

78 (Dumanowski *et al.*, 2025) - and obtained the adjusted angles required to calculate Pleasantness  
 79 and Eventfulness (Table 1). Thus, a methodology for proper soundscape assessment in the  
 80 Polish language is now established.

81 It should be noted that the correction angles affect only the transformation of raw attribute  
 82 assessments into the Pleasantness–Eventfulness circumplex and not the soundwalk procedure  
 83 or the perceptual judgments. Pleasantness and Eventfulness are calculated using language-  
 84 specific correction angles to ensure cross-language and cross-cultural compatibility, while  
 85 variations in angle values affect only the numerical positioning within the two-dimensional  
 86 space.

87 The subsequent sections of this paper present the procedure and results of the first pilot  
 88 soundwalk employing the validated Polish attributes and the calculation of Pleasantness and  
 89 Eventfulness using the Polish correction angles.

90 Table 1. Polish translation of ISO/TS 12913-2:2018 soundscape attributes with  
 91 obtained adjustment angles.

ISO/TS 12913-2:2018 soundscape attribute	ISO/TS 12913-3:2019 original angle	Validated Polish translation	Obtained Polish adjustment angle
Pleasant	0°	Przyjemne	0°
Vibrant	45°	Tętniące życiem	69°
Eventful	90°	Bogate w wydarzenia	91°
Chaotic	135°	Chaotyczne	128°
Annoying	180°	Dokuczliwe	176°
Monotonous	225°	Monotonne	266°
Uneventful	270°	Ubogie w wydarzenia	274°
Calm	315°	Spokojne	339°

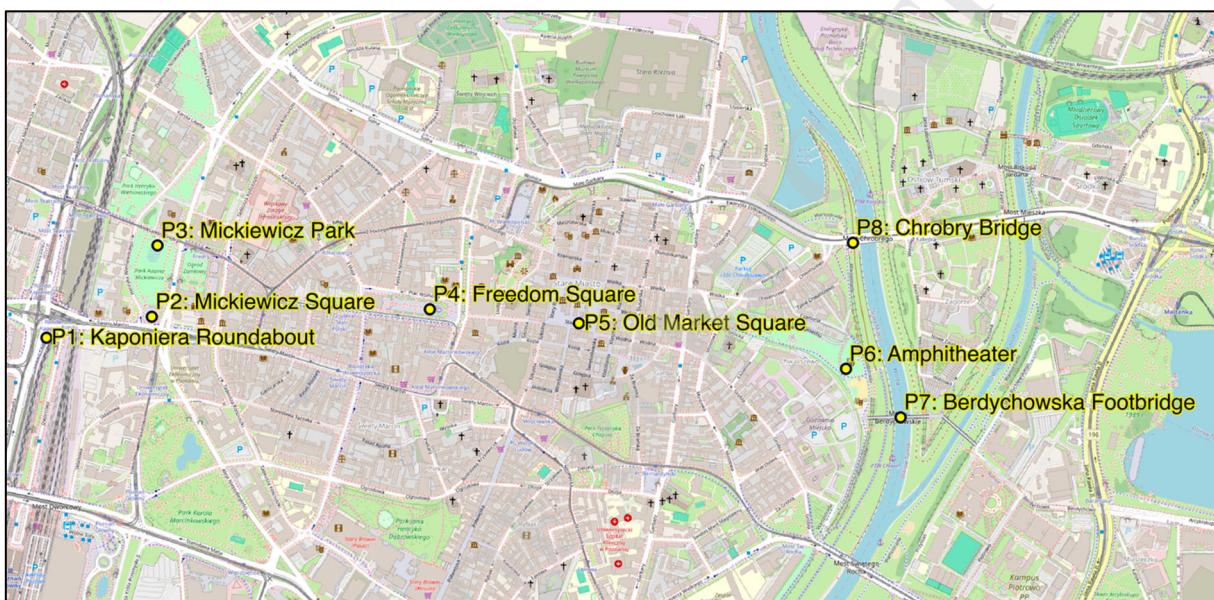
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### 93 3. Methods

#### 94 3.1. Soundwalk route

95 On 13 May 2025 a soundwalk was carried out in the center of Poznań, Poland under dry, calm  
 96 weather conditions (wind speed below 3 m/s, temperature 18.5 °C, relative humidity 38 %).  
 97 The route comprised eight evaluation points (see Fig. 2) and ran from Kaponiera Roundabout  
 98 to Chrobry Bridge. The first stop, P1, was the large, traffic-intensive Kaponiera Roundabout  
 99 (*Rondo Kaponiera*); P2 was Mickiewicz Square (*Plac Mickiewicza*) beside St. Martin Street;

100 P3 led into Mickiewicz Park (*Park Mickiewicza*), a green space with a fountain beside Fredry  
 101 Street. P4, Freedom Square (*Plac Wolności*), is another central plaza with a fountain, while P5,  
 102 Old Market Square (*Stary Rynek*), represents historical center of the city. From there the walk  
 103 continued to P6, the Amphitheater (*Amfiteatr*) in a riverside park next to the cultural-  
 104 recreational KontenerART area, proceeded across P7, the Berdychowska Footbridge (*Kładka*  
 105 *Berdychowska*) over the Warta River, and concluded at P8, Chrobry Bridge (*Most Chrobrego*),  
 106 which spans the Warta River and links the heavily trafficked Estkowskiego Street and  
 107 Wyszyńskiego Street.



108  
 109 Fig. 2. Soundwalk points in Poznań on map background (OpenStreetMap contributors, n.d.)  
 110

### 111 3.2. Participants

112 Thirteen participants (5 females, 8 males; age range 22-73 years;  $M_{age} = 29$ ,  $SD_{age} = 14.4$ ) took  
 113 part in the soundwalk. The group consisted of acoustics students along with three lecturers  
 114 from Adam Mickiewicz University.

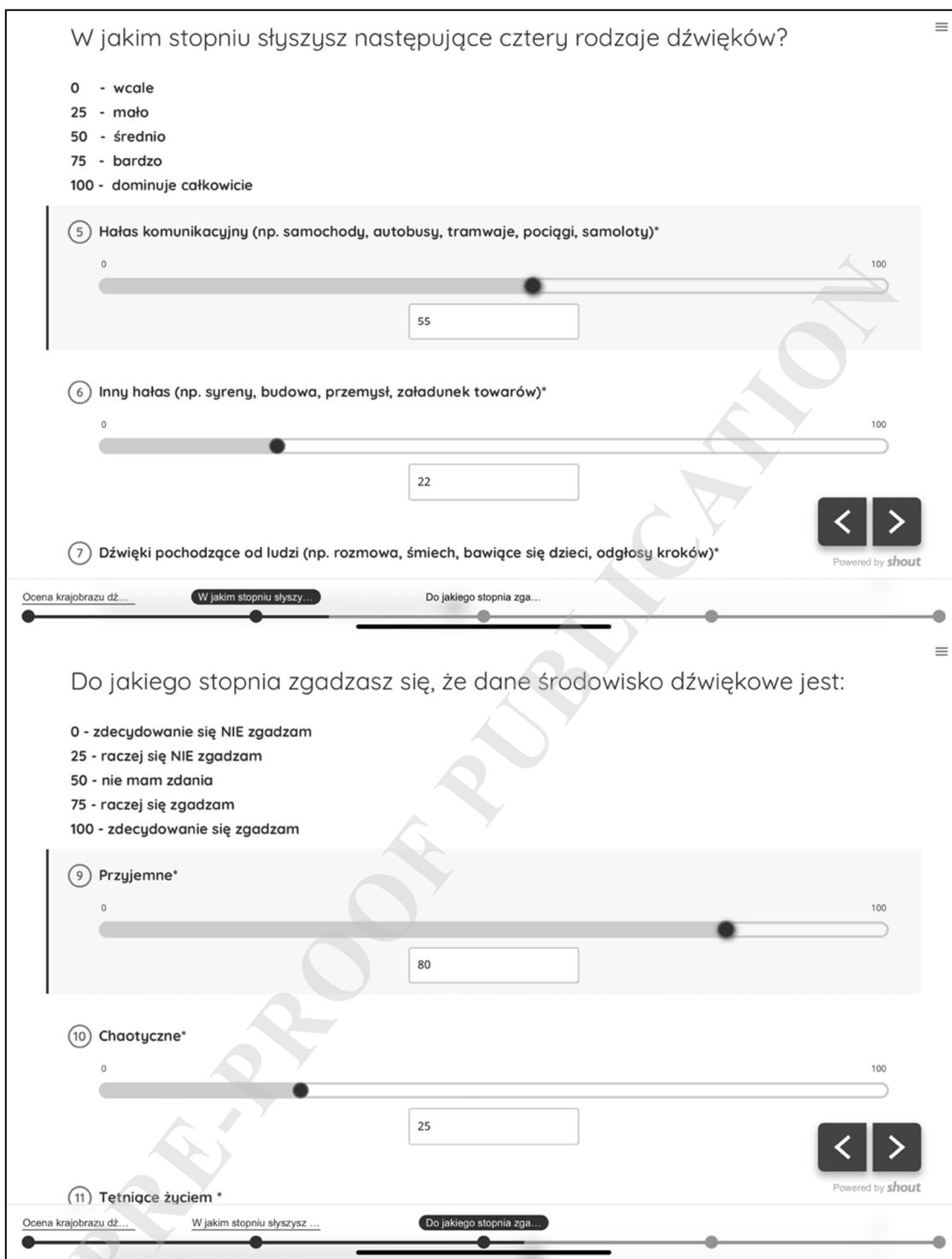
### 115 3.3. Procedure

116 At each point the participants evaluated the soundscape using the Polish-language soundscape  
 117 questionnaire translated from ISO 12913-2:2018. The survey was hosted online: participants  
 118 scanned a QR code that redirected them to a pre-prepared questionnaire (FreeOnlineSurveys,  
 119 n.d.). Within the form (Fig. 3) they identified audible sound sources, rated the eight  
 120 soundscape attributes and could enter free comments. All ratings were given on interactive

121 sliders ranging from 0 to 100. The structure of our questionnaire was inspired by the survey  
122 used in the article by Mitchell *et al.* (2020).

123 For sound-source identification the question read: “To what extent do you presently hear the  
124 following four types of sounds? (0 - not at all, 100 - dominates completely).” The four  
125 categories presented were: traffic noise (e.g. cars, buses, trams, trains, airplanes), other noise  
126 (e.g. sirens, construction work, industrial activity, loading of goods), human sounds (e.g.  
127 conversation, laughter, children playing, footsteps), and natural sounds (e.g. birdsong, flowing  
128 water, wind in vegetation).

129 For the attribute assessment (pleasant, vibrant, eventful, chaotic, annoying, monotonous,  
130 uneventful, calm) it read: “To what extent do you agree or disagree that the present surrounding  
131 sound environment is...? (0 - strongly disagree, 100 - strongly agree).” The soundscape  
132 evaluation at each location lasted approximately five minutes.



134 Fig. 3. Screenshots of the Graphical User Interface for evaluating soundscape using an online  
135 questionnaire (FreeOnlineSurveys, n.d.).

136  
137 While the questionnaire was being completed, binaural audio, ambisonic audio and 360° video  
138 were recorded simultaneously (see Fig. 4 for the recording setup). A calibrated recording  
139 device (HEAD acoustics, 2014) with binaural microphones (HEAD acoustics, 2023a) was  
140 used, enabling subsequent extraction of equivalent sound levels and psychoacoustic

141 parameters from the recorded samples. The visual environment was captured using a 360°  
142 camera (GoPro Inc., 2019), while ambisonic audio was recorded using a first-order ambisonic  
143 microphone (RØDE Microphones, 2018) with a multichannel audio recorder (Zoom  
144 Corporation, 2019).



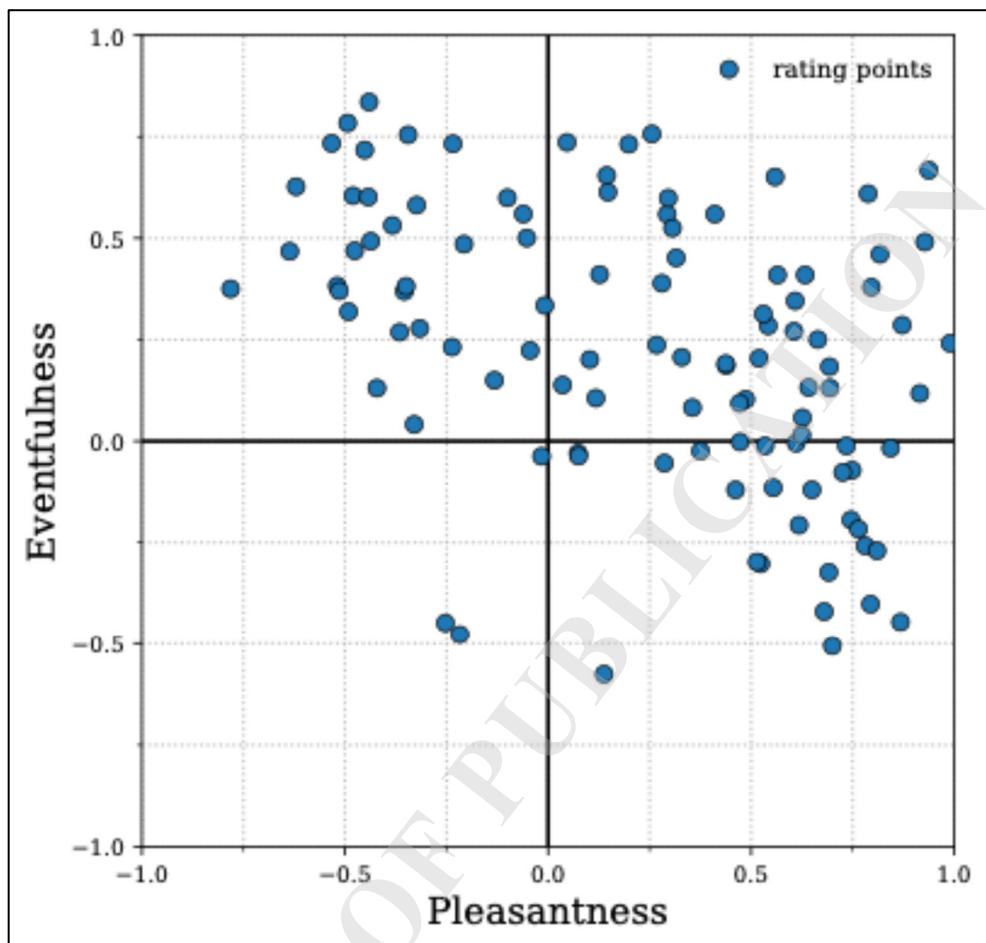
145  
146 Fig. 4. Recording setup - binaural microphones, ambisonic microphone and 360° video  
147 camera  
148

149 **4. Results**

150 *4.1. Participants' subjective soundscape evaluations*

151 Based on the ratings of the eight soundscape attributes, the indices Pleasantness and  
152 Eventfulness were computed using Equations 1-4. Figure 5 plots every single assessment (all  
153 participants at all eight points) to illustrate the spread across the two-dimensional Eventfulness-  
154 Pleasantness space. Figure 6 shows the individual Eventfulness-Pleasantness ratings for the  
155 eight Poznań locations made by the 13 soundwalk participants, together with the median value  
156 for each site. Kernel-density contours representing the 10<sup>th</sup>, 25<sup>th</sup>, 50<sup>th</sup> and 75<sup>th</sup> percentiles are  
157 superimposed to visualize the concentration of responses. Figure 7 presents the mean perceived

158 prominence of the four predefined sound-source categories at each location; error bars indicate  
159 the 95 % confidence intervals.



160  
161 Fig. 5. All participants' ratings at all eight locations mapped onto Eventfulness-Pleasantness  
162 coordinate system.

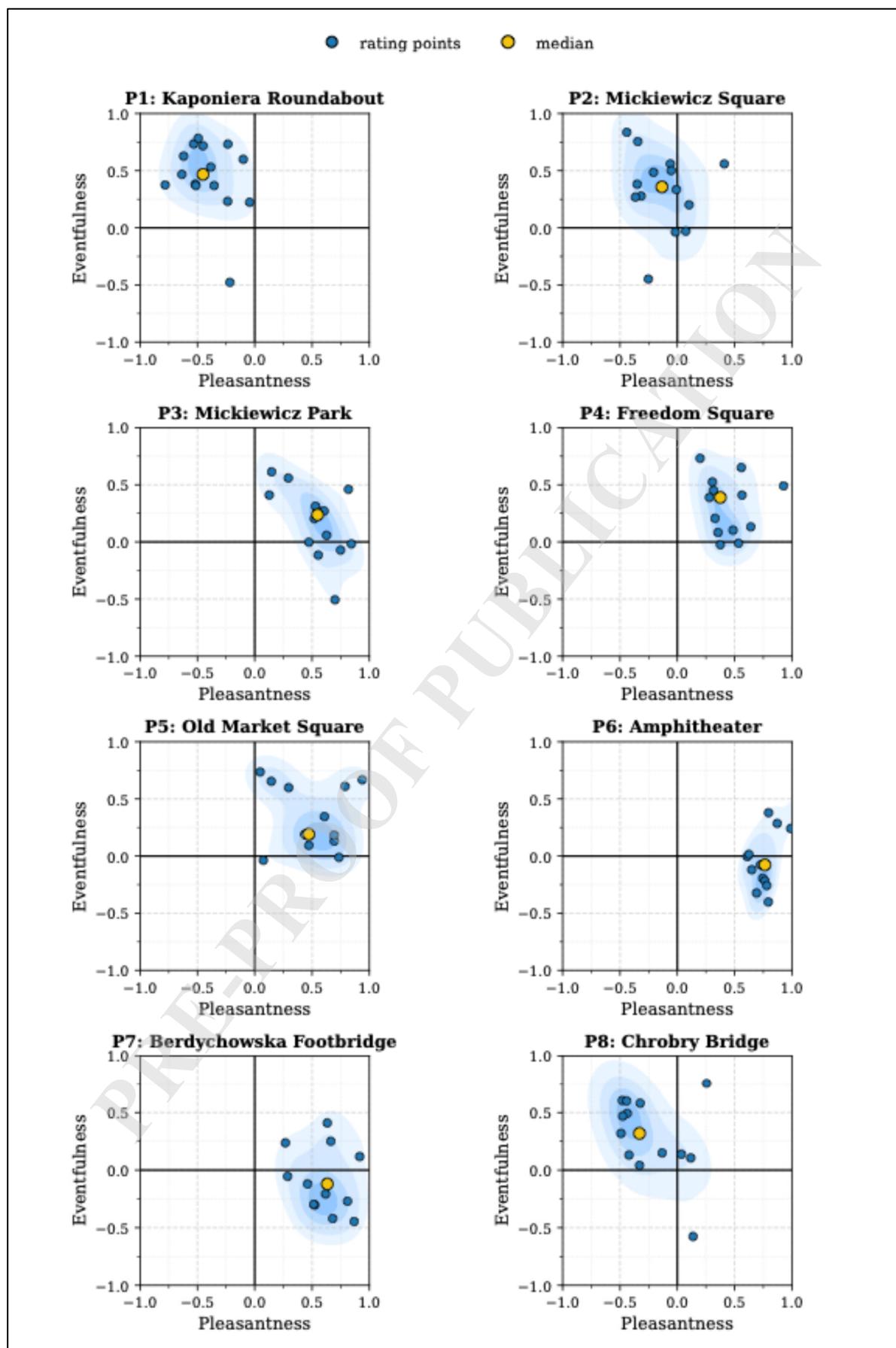


Fig. 6. Eventfulness-Pleasantness ratings for each of the eight locations in Poznań.

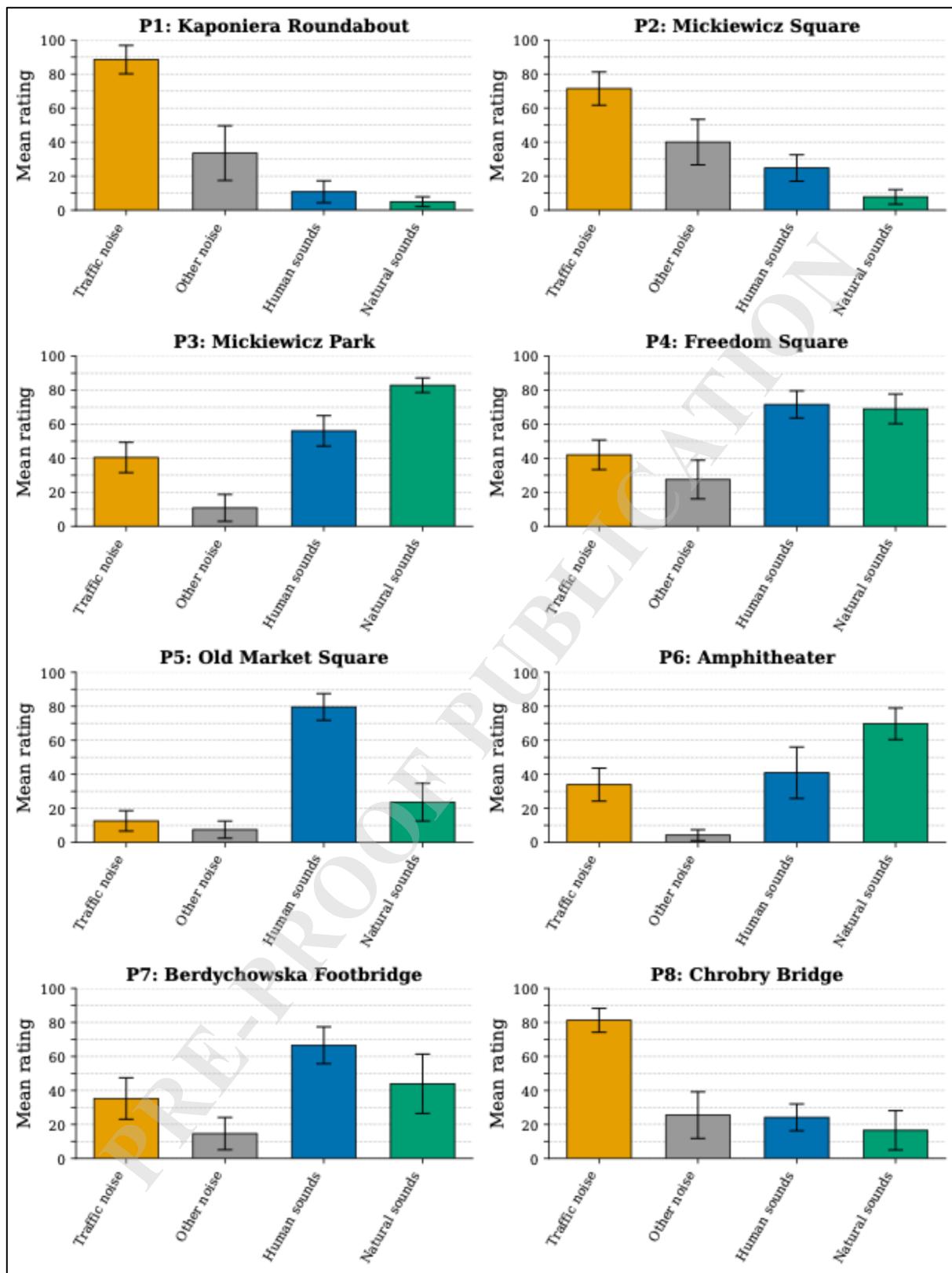


Fig. 7. Mean value of perceived prominence of the four predefined sound-source categories at each location.

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#### 4.2. Objective parameters calculated from binaural recordings

170 In accordance with the requirements of ISO/TS 12913-3:2019, objective acoustical parameters  
 171 - equivalent sound level ( $L_{Aeq}$ ), loudness, N5, N95, sharpness, fluctuation strength, roughness  
 172 and tonality - were extracted from approximately five-minute binaural recordings at each of  
 173 the eight measurement points using standard-compliant sound analysis software (HEAD  
 174 acoustics, 2023b). Because binaural recordings provide separate left- and right-ear channels,  
 175 the channels were processed individually. In line with the standard, the higher of the two  
 176 values was retained for every descriptor. The values of all calculated objective parameters are  
 177 listed in Table 2. A visual representation of this data is shown in Figure 8.

178 Table 2. Objective parameters of eight evaluated locations, calculated from binaural  
 179 recordings.

Location	P1: Kaponiera Roundabout	P2: Mickiewicz Square	P3: Mickiewicz Park	P4: Freedom Square	P5: Old Market Square	P6: Amphitheater	P7: Berdychowska Footbridge	P8: Chrobry Bridge
$L_{Aeq}$ [dB]	85.9	66.9	68.3	59.1	61.8	53.8	55.8	72.3
Loudness [sone]	53.8	24.4	24.7	15.2	16.4	10.0	11.3	29.6
N5 [sone]	45.1	25.9	26.9	18.4	16.2	10.7	13.8	35.7
N95 [sone]	12.5	13.9	21.2	11.4	10.2	5.2	5.2	11.6
Sharpness [acum]	2.45	2.02	3.94	2.60	2.15	1.69	1.80	2.44
Fluctuation Strength [vacil]	0.08	0.05	0.01	0.01	0.02	0.01	0.02	0.01
Roughness [asper]	0.04	0.05	0.03	0.02	0.03	0.02	0.03	0.04
Tonality [tuHMS]	0.21	0.26	0.14	0.16	0.18	0.17	0.15	0.16

180

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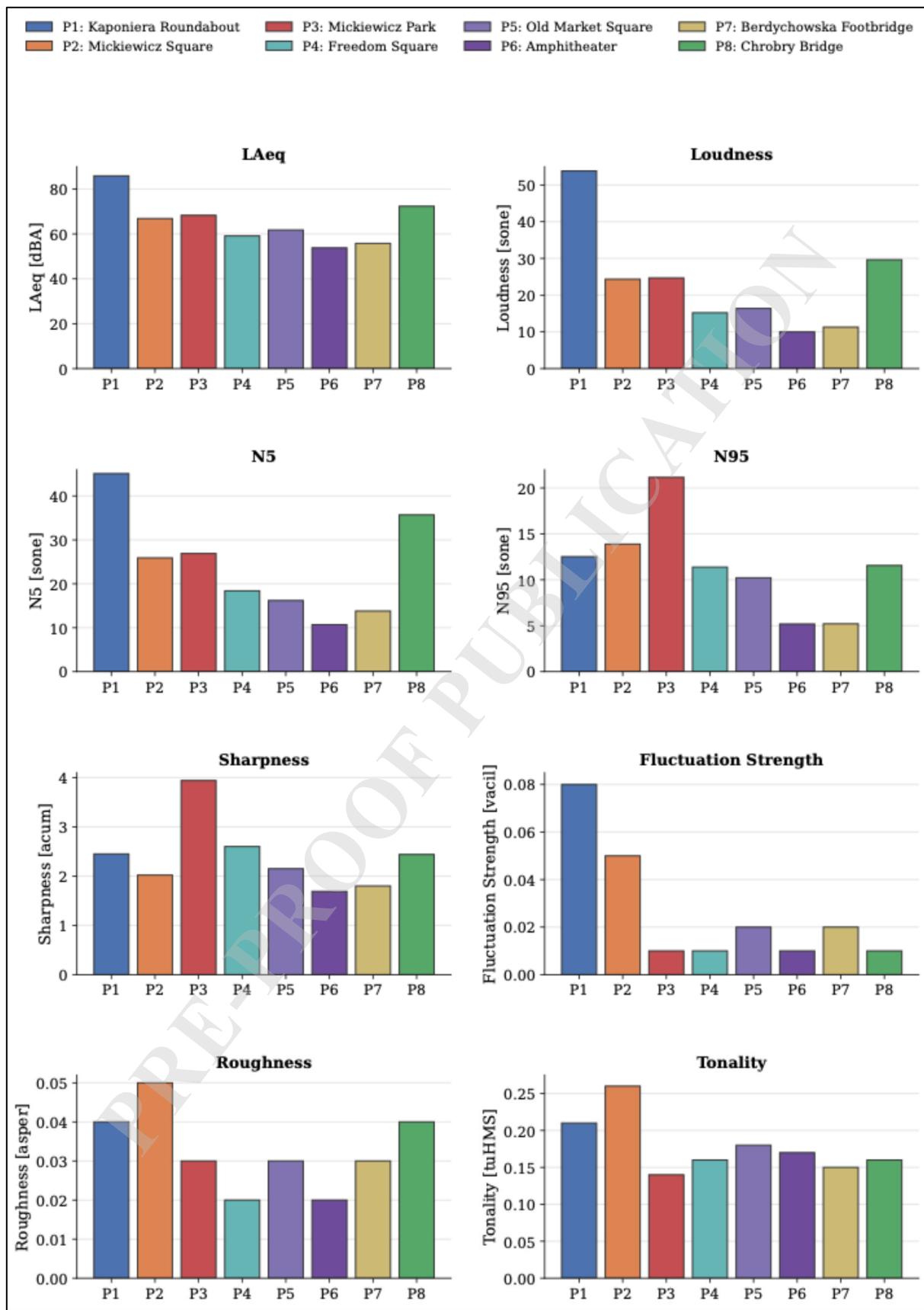


Figure 8. Objective parameters across eight evaluated locations.

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185 P1: Kaponiera Roundabout shows the highest values of  $L_{Aeq}$ , loudness, N5, and fluctuation  
186 strength, as well as the highest median Eventfulness, while recording the lowest median  
187 Pleasantness. P3: Mickiewicz Park has the greatest background loudness (N95) and the highest  
188 sharpness value, and its soundscape contains the largest share of natural sounds. At P2:  
189 Mickiewicz Square, traffic noise dominates, yet among all eight sites this square also contains  
190 the highest proportion of “other” noises; it exhibits the greatest roughness and tonality. At P5:  
191 Old Market Square, human sounds represent the largest share of the soundscape. The most  
192 favorable soundscape is found in the P6: Amphitheater, where  $L_{Aeq}$ , loudness, N5, N95,  
193 sharpness, and roughness reach their lowest values, and Pleasantness is the highest of all  
194 locations. The lowest median Eventfulness is observed on P7: Berdychowska Footbridge.

## 195 5. Discussion

196 The individual-level data reveal a considerable spread, an expected consequence of the  
197 subjective nature of the ratings. One way to tighten the dispersion could be to brief participants  
198 beforehand on how each soundscape attribute should be interpreted; yet such instruction might  
199 introduce response bias. Although ISO 12913-2 recommends a minimum of 20 respondents,  
200 the present study was conceived as a pilot intended to test the in-situ applicability of the Polish  
201 attribute set.

202 All judgments were made on a continuous 0-100 slider rather than on the five-point Likert  
203 scale suggested by ISO 12913-2:2018. The finer 101-point resolution offers greater numerical  
204 precision when computing Pleasantness and Eventfulness. While this would be impractical  
205 with paper forms, the online survey interface made the slider implementation straightforward.  
206 A future experiment could explicitly compare the 0-100 slider with the five-step Likert format.

207 A few participants scored Eventfulness markedly differently from the majority, possibly  
208 because the Polish terms “bogate w wydarzenia” and “ubogie w wydarzenia” were  
209 misunderstood, or because momentary lapses of attention led to reversed ratings.

210 As expected, soundscapes dominated by traffic noise received lower Pleasantness scores than  
211 those characterized by human voices or natural sounds, confirming earlier findings (Nilsson,  
212 Berglund, 2006; Nilsson *et al.*, 2007; Axelsson *et al.*, 2010). According to Schafer’s (1993)  
213 typology, the sites studied can be classified as hi-fi environments (P3: Mickiewicz Park, P4:  
214 Freedom Square, P5: Old Market Square, P6: Amphitheater, P7: Berdychowska Footbridge)  
215 and lo-fi environments (P1: Kaponiera Roundabout, P2: Mickiewicz Square, P8: Chrobry

216 Bridge). In general, high  $L_{Aeq}$  and high loudness are associated with low Pleasantness, whereas  
217 low values of these measures coincide with high Pleasantness. This relationship is clear in very  
218 quiet and very loud contexts, where N5, loudness and  $L_{Aeq}$  are good predictors of the  
219 Pleasantness. In the mid-range of sound levels, the pattern weakens and exceptions emerge. For  
220 instance, P3: Mickiewicz Park was rated more pleasant than P2: Mickiewicz Square even  
221 though it showed higher  $L_{Aeq}$ , loudness, N5, N95 and sharpness, probably due to the fountain's  
222 masking effect and the presence of human voices and natural sounds. In contrast to level-related  
223 metrics, parameters describing temporal and tonal sound characteristics, such as fluctuation  
224 strength, sharpness, roughness and tonality, were not significantly associated with either  
225 Pleasantness or Eventfulness.

226 These results indicate that sound level alone is insufficient to predict soundscape quality. They  
227 support the view that "informational properties of soundscapes (i.e., categories of sounds) are  
228 better predictors of perceived soundscape quality than acoustic measures such as  $L_{Aeq}$ "  
229 (Axelsson *et al.*, 2010; Nilsson, 2007).

## 230 **6. Conclusions**

231 The study presented an evaluation of eight locations in Poznań during a pilot soundwalk  
232 conducted in accordance with ISO/TS 12913-2:2018, using the validated Polish version of the  
233 soundscape attributes. The proposed methodology establishes a reference framework for Polish  
234 soundscape studies and can guide the design of more people-friendly urban acoustic  
235 environments. Future work should recruit a larger and more diverse participant pool (beyond  
236 individuals linked to acoustics) and include sites that are monotonous. Follow-up studies might  
237 also apply the soundscape assessment protocol in laboratory settings to complement the in-situ  
238 findings.

## 239 FUNDINGS

240 This research did not receive any specific grant from funding agencies in the public,  
241 commercial, or not-for-profit sectors.

## 242 CONFLICT OF INTEREST

243 The authors declare that they have no known competing financial interests or personal  
244 relationships that could have appeared to influence the work reported in this paper.

245

## AUTHORS' CONTRIBUTION

246 Jakub Dumanowski (conceptualized the study, wrote the original draft, prepared the surveys  
247 and the sound walk, developed the methodology, curated the data, performed the analysis, and  
248 created the visualizations). Anna Preis (developed the methodology, prepared and supervised  
249 the sound walk, and conceptualized the study). Jan Felcyn (performed the analysis, curated the  
250 data, and contributed to data interpretation). All authors reviewed and approved the final  
251 manuscript.

252

## ACKNOWLEDGMENTS

253 The authors would like to thank Eryk Kozłowski for his assistance with the organization and  
254 the audiovisual recordings, and the first-year Acoustics students of Adam Mickiewicz  
255 University in Poznań for participating in the soundwalk.

256

257

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