

SOUNDSCAPE AS AN URBAN TRANSFORMATION TOOL / ECHOES OF NEW BELGRADE

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ABSTRACT

The soundscape, understood as the acoustic environment perceived by humans, plays a fundamental role in shaping spatial experiences. This research examines how auditory perception can be used as a tool in urban design, with a specific focus on the soundscapes of urban areas in New Belgrade. By analysing the role of sound in the formation of urban identities and communities, the study seeks to identify locations that could benefit from targeted acoustic interventions. This primary goal of the study is to quantitatively measure noise pollution levels in several residential blocks of New Belgrade. To minimise and control relative error during measurements, various phonometers and applications will be used to accurately analyse sound levels. A key outcome of the research is the creation of a sound map for selected residential blocks in New Belgrade. This sound map will serve as a foundation for future surveys on residents' perceptions of noise pollution and their perspectives on potential remediation strategies aimed at enhancing the quality of life in their neighborhoods. The results will aim to develop guidelines for spatial interventions that could improve the quality of life within local communities of New Belgrade by identifying areas that would benefit from targeted interventions to enhance the acoustic environment. Additionally, the research will provide insights into how soundscapes influence the perception of public space and propose new approaches for integrating auditory elements into urban planning.

KEYWORDS _ *Soundscapes, acoustic mapping, New Belgrade, atmospheric narratives*

INTRODUCTION

Human perception of sound has always been a source of fascination, as how people hear and interpret the surrounding sounds deeply influences their experience of place and urban identities. Sound, when understood as an environment, is a soundscape: a powerful tool that helps humans relate to their surroundings. The soundscape can be defined as “the auditory environment as perceived, experienced and/or understood by the listener”. The study of these human-sound relationships being called acoustic ecology was pioneered by R. Murray Schafer in the late 1960s with the founding of the World Soundscape Project. Since Murray Schafer’s pioneering work on acoustic ecology, researchers have advanced from treating urban sound merely as unwanted noise to recognising its potential as a design resource. Building on this, Barry Truax in the 1978 Handbook for Acoustic Ecology established systematic methods for listening, recording and analysing our sonic surroundings. Truax codified systematic methodologies for perceptual recording and classification of acoustic data, outlining practices such as soundwalking, analytic listening modes and community workshops that enable researchers to document human-environment sonic interactions. These foundational texts establish that soundscapes are not merely background noise but structured environments with measurable properties and culturally embedded meanings. In the late 1990s, acoustic ecology extended into a formal science—soundscape ecology—by situating human-centred listening within broader ecological systems (Pijanowski et al, 2011). Bioacoustician Bernie Krause defined three interacting acoustic domains: *biophony* (biological sounds), *geophony* (natural non-biological sounds) and *anthrophony* (human-generated sounds). This tripartite model highlights how urban form and human activities generate distinct acoustic patterns, and how those patterns both reflect and influence coupled human–environment processes. In the dense, modernist blocks of New Belgrade, anthrophonic sources dominate (e.g. traffic, HVAC systems, human activity). However, opportunities exist to enhance biophonic and geophonic elements through certain design interventions. To understand how such design can alter targeted environments, many of researchers have looked to understand the urban setting in this manner. One of such is a study done in Antwerp. For example, it has shown that green buffer zones and quiet pedestrian corridors can mitigate traffic noise and create positive “soundmarks” that strengthen community identity (De Coensel & Botteldooren, 2010).

Despite growing interest in soundinformed urban design, few studies have tested the measurement reliability of lowcost and mobile acoustic tools in dense postsocialist housing estates. Addressing this gap, the present research is defined as a pilot study which quantifies the relative error in measuring noise pollution levels within selected New Belgrade blocks by using multiple phonometers alongside validated smartphone applications. Establishing the reliability of this measurement protocol will provide a robust framework for future research into targeted acoustic interventions and participatory soundscape planning in urban design. By validating affordable measurement approaches in the specific urban morphology of New Belgrade, this research lays the groundwork for subsequent perceptual surveys and spatial intervention strategies aimed at improving acoustic comfort.

METHODOLOGY

Theoretical research was focused on the literature review of secondary resources in the domain of soundscapes and sonic urban design. The second part of the research was developed as a preparation for a pilot study aimed at quantitatively measuring noise levels and recording anthrophony for subsequent processing. This pilot study is focused on a section of New Belgrade blocks covering an area of approximately 20 hectares. In this study, two measurement tools were operated simultaneously at each sampling location to quantify relative error and test the reliability of acoustic measurement protocols. The measurement tools were: 1) *BENETECH GM1352 sound level meter*- a handheld digital sound level meter with a measurement range of 30 dB to 130 dB, resolution of 0.1 dB and accuracy of ± 1.5 dB; 2) *the Decibel X – dB Sound Level Meter* smartphone application on iOS. Measurements were taken in four diurnal intervals—early morning (06:00–09:00), daytime (09:00–16:00), afternoon

(16:00–23:00) and night (23:00–06:00)—with at least three independent readings per device in each interval. This replication under varied conditions allowed calculation of device-to-device relative error and ensured that transient fluctuations did not bias results. Each measurement was geotagged, timestamped, then compiled into a dataset for statistical and spatial analysis. Quantitative methods of research included calculation of descriptive statistics (mean, standard deviation) for each interval, identification and treatment of outliers, inferential error analysis (devicetodevice bias, limits of agreement) and geospatial interpolation (kriging) to generate continuous acoustic heatmaps.

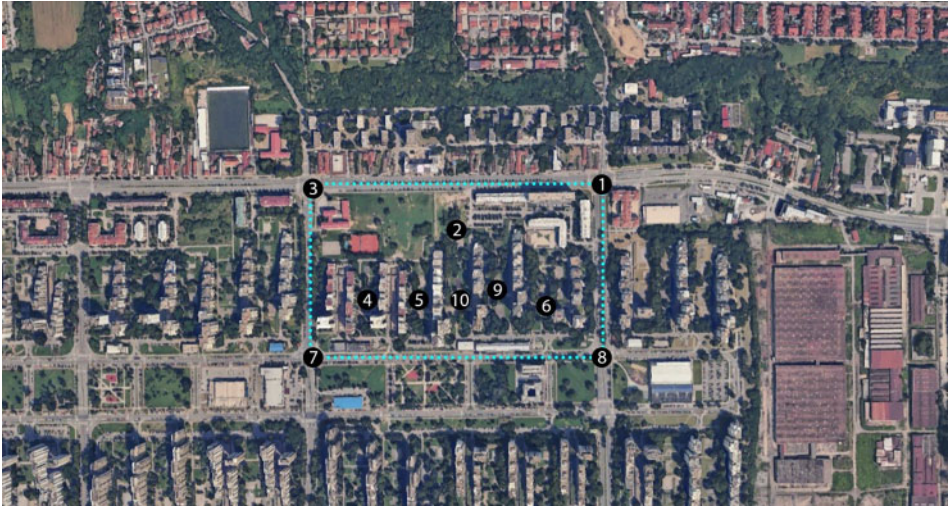


Figure 1: Pilot study area boundary, New Belgrade, block 63

THEORETICAL FRAMEWORK

Chronic exposure to environmental noise is recognised by the World Health Organization as a significant threat to public health, linked to elevated blood pressure, increased risk of cardiovascular disease and sleep disturbance (WHO, 2000). As the UK Acoustics Community observes, “poor soundscape quality affects the health and wellness of humans in all environments encountered,” while the presence of natural acoustic elements delivers “psychological noise masking” that can alleviate stress and promote recovery (Smith et al., 2018). Soundscape ecology frames these acoustic environments as integrated socio-ecological systems in which biophonic (natural) and geophonic (non-biological natural) sounds can play a restorative role by masking harmful noise and reducing perceived stress (Pijanowski et al., 2011). A comprehensive review of soundscape science further emphasises that “quiet alone is insufficient”—environments enriched with positive natural sounds often yield greater well-being benefits than silence itself (Jones & Brown, 2019). Yet, before any targeted intervention can be designed, the existing sound conditions must be fully documented. Only with a validated acoustic map can subsequent perceptual surveys and spatial interventions be credibly planned to mitigate health risks and introduce restorative sound elements into the urban fabric.

DATA COLLECTING

Measurement point selection

The study area is residential Block 63 in New Belgrade, defined by Vojvođanska Street (north), Japanska Street (south), Gandijeva Street (east) and Nehruova Street (west). Ten measurement

points were chosen to capture noise at both the edges and inside the block. Four points sit along the block's perimeter adjacent to major roads, while six lie within the central courtyards, covering children's playgrounds, a basketball court and landscaped green spaces. Figure 1 shows all sampling locations, allowing comparison between noisy edges and quieter interior areas:

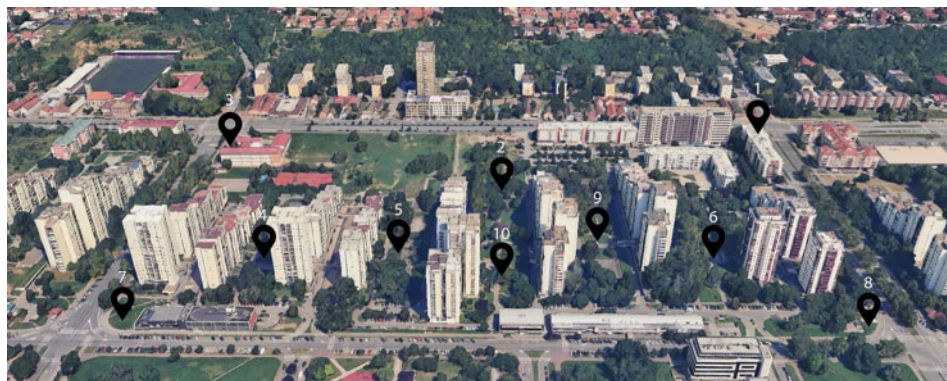


Figure 2: Measuring locations (1-10)

Point 1 – Intersection of Vojvođanska and Gandijeva; **Point 2** – Parking area and basketball court; **Point 3** – Intersection of Vojvođanska and Nehruova; **Point 4** – Park Ten; **Point 5** – Park Eleven; **Point 6** – Park Fourteen; **Point 7** – Intersection of Japanska and Nehruova, small seating area; **Point 8** – Intersection of Japanska and Gandijeva; **Point 9** – Interior courtyard and sports courts; **Point 10** – Playground for the youngest users.

RESULTS

The measurement results for this study are presented in two complementary formats: tables and heatmaps. Each format interprets the measurements in its own distinctive way, which is crucial for understanding the effectiveness of the entire procedure and for drawing key conclusions. Additionally, these dual representations allow for cross-validation between quantitative statistics and spatial patterns, ensuring a solid basis for subsequent analysis and intervention planning.

First, a comprehensive set of tables displays the minimum and maximum noise levels recorded at each sampling zone (1-10) for both the handheld phonometer and the smartphone app. These tables establish the quantitative foundation of the analysis by highlighting the lowest and highest values drawn from all individual readings. Direct comparison of the two devices reveals systematic discrepancies, while calculations of average, minimum and maximum noise levels for each zone and time interval provide a clear numerical profile of the block's acoustic conditions. In addition, the tabulated data facilitate the identification of outliers—those unusually high or low readings—and document daily fluctuations in sound levels, providing an assessment of reliability of the measurement protocol.

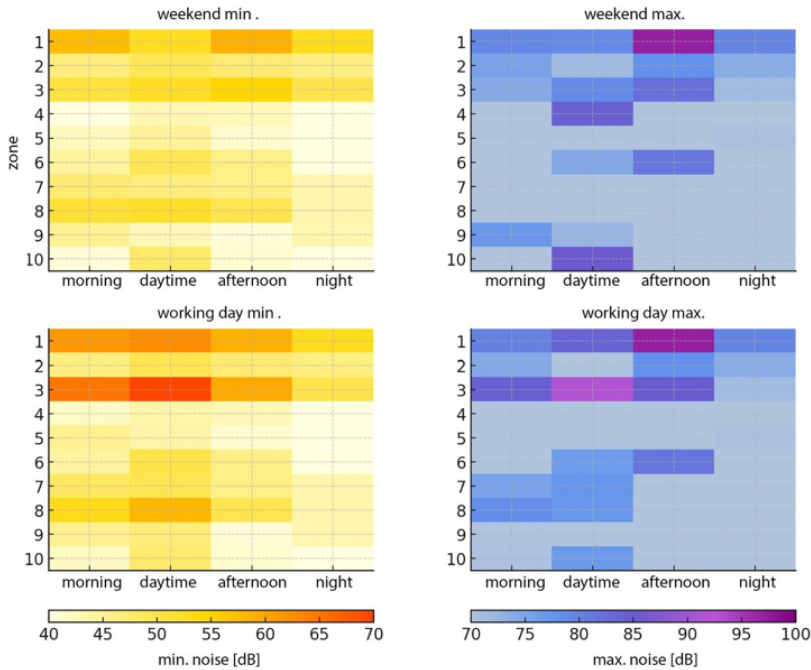
Table 1: Noise measuring during the weekend (raw data)

Extrema (minimum)		1	2	3	4	5	6	7	8	9	10
MORNING	phonometer	57.7	46.6	50.8	39.1	42.3	44.4	47.2	51.3	45.1	40.6
	mobile app	53	44.6	50.5	37.3	40.3	42.7	44.8	49	43.3	39.6
DAYTIME	phonometer	52.7	49.2	52.5	43.1	44.8	49.3	46.6	52.2	42.7	48
	mobile app	52.9	46.7	49.9	41.2	42.8	45.3	45.5	48	40.5	46.3
AFTERNOON	phonometer	58.8	47.2	55.1	42.8	41.2	45.8	46	49.5	40.7	41.1
	mobile app	56.6	45.3	52.1	41.9	40.4	42.5	43.4	45.5	40.1	39.1
NIGHT	phonometer	53	46.4	49.8	36.6	38.6	39.4	43.5	43.4	43.2	40.2
	mobile app	54.3	45.5	53.8	35.7	37	35.8	39.4	40.3	41.3	39.2
Extrema (maximum)		1	2	3	4	5	6	7	8	9	10
MORNING	phonometer	79.2	75.4	74	59.1	53.5	54.7	56.3	69.8	76.9	59.3
	mobile app	82.6	85.4	82.5	70.1	54.3	53.8	55.9	68.4	74.4	60.8
DAYTIME	phonometer	78.8	71.6	78.9	84	67.3	74.4	65.6	69.9	72.3	85.4
	mobile app	80.7	76.3	80.5	87.3	70	71.2	67.3	69.5	71	88.6
AFTERNOON	phonometer	97.1	77.8	82.3	70	67.5	81.4	70	69.9	66.2	66.3
	mobile app	95	71.6	81.7	65.8	61.5	77.5	68.9	78.8	62	58.7
NIGHT	phonometer	79.4	73.8	71.4	67.1	70.5	67.1	69.9	68.1	62.7	58.7
	mobile app	81.7	77.7	75.8	58.9	64.9	70.6	70	63.6	70.4	59.9

Table 2: Noise measuring during the work days (raw data)

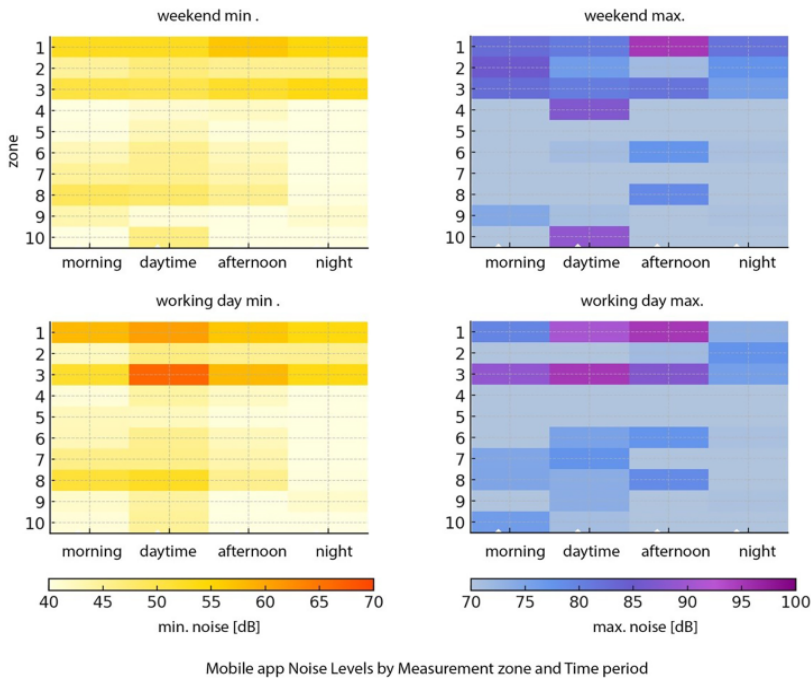
Extrema (minimum)		1	2	3	4	5	6	7	8	9	10
MORNING	phonometer	61.3	46.3	64.9	41.8	45.3	44.3	48.5	53.3	45.2	42.1
	mobile app	57.9	42.3	52.1	40.6	42.5	42.8	45.8	51.1	41.5	40.5
DAYTIME	phonometer	62.5	49.5	72.5	43.7	43.8	50	49.4	58.2	46.8	47.5
	mobile app	60.6	46.5	66.6	44.2	42.3	45.4	45.8	52.6	44.3	44.8
AFTERNOON	phonometer	58.8	47.2	59.6	42.8	41.2	45.8	46	49.5	40.7	41.1
	mobile app	56.6	45.3	58	41.9	40.4	42.5	43.4	45.5	40.1	39.1
NIGHT	phonometer	53	46.4	49.8	36.6	38.6	39.4	43.5	43.4	43.2	40.2
	mobile app	54.2	45.5	53.8	35.7	37	35.8	39.4	40.3	41.3	39.2
Extrema (maximum)		1	2	3	4	5	6	7	8	9	10
MORNING	phonometer	80	74.3	84.2	66.8	69.9	69.2	75.5	78.4	68.6	70.3
	mobile app	79.5	69.3	88.8	64	69.9	69.1	74.7	74.9	65.1	76.3
DAYTIME	phonometer	83.5	69.1	91.8	69.7	66	76.4	77.3	76.8	68.1	76.6
	mobile app	90.8	61.7	95	60.5	58.9	75.4	77.7	73.7	73.7	71.1
AFTERNOON	phonometer	97.1	77.8	84.6	70	67.5	81.4	70	69.6	66.2	66
	mobile app	95	71.6	87.4	65.8	61.5	77.5	68.9	78.7	62	58.7
NIGHT	phonometer	79.4	73.8	71.4	67.1	70.5	67.1	69.9	68.1	62.7	58.7
	mobile app	73.5	77.7	75.8	58.9	64.9	70.6	70	63.6	70.4	59.9

In contrast, the second type of data representation are the heatmaps which translated those numerical results into a spatial context. Divided by the time periods (morning, daytime, afternoon, night) and measuring points (1-10) as stated in Figures 1 and 2, we can see which zones are the quietest or most exposed to noise and in which measurement interval. The heatmaps mapped noise distribution across the block, clearly illustrating the gradient from traffic-exposed edges to quieter interior courtyards. In this way, the tables give us a numerical insight and confirm the reliability of the data, and the heatmap graphics turn those figures into easy-to-understand maps for spatial planning.



Phonometer Noise Levels by Measurement zone and Time period

Figure 3: Noise level measurements differentiated by Zones and Time periods (phonometer)



Mobile app Noise Levels by Measurement zone and Time period

Figure 4: Noise level measurements differentiated by Zones and Time periods (mobile app)

DISCUSSION

The comparison of every paired reading from the smartphone app and the handheld phonometer shows that, on average, the app reads about 1.78 dB higher than the phonometer (mean bias = +1.78 dB). When all deviations (both under and overestimates) are considered without sign, the mean absolute error is 3.85 dB. This quantified error range should be taken into account when using the app's data for acoustic mapping and planning interventions. Breaking this down by minima and maxima:

- The app's minimum readings exceed the phonometer's by an average of +2.34 dB.
- The app's maximum readings exceed the phonometer's by an average of +1.22 dB.

The heatmaps reveal a clear gradient between edge and interior zones. Perimeter points (1–4, 7–8) record substantially higher minimum and maximum noise levels—minima around 60–70 dB and peaks above 85 dB in the afternoon—while interior courtyard and recreational points (5–6, 9–10) remain quieter, with minima of 45–55 dB and maxima generally below 80 dB. Diurnal patterns show the highest noise during the afternoon, corresponding to traffic rushhour and outdoor activities. Nighttime levels drop by 10–15 dB across all zones, confirming reduced anthropogenic sources. Weekend minima in interior zones are slightly lower than on weekdays, but peak levels remain similar, indicating occasional loud events even on quieter days. Device comparison indicates close agreement on minima (average bias < 2 dB), while the smartphone app tends to underestimate afternoon peaks by 3–5 dB relative to the sound level meter, suggesting slight highlevel compression. Outlier analysis flagged several extreme peaks (> 95 dB) at peripheral intersections during the afternoon, which were retained to reflect true worstcase conditions. By establishing both the error bounds of accessible measurement tools and the precise spatial pattern of noise within a New Belgrade block, this pilot study reveals a previously unquantified opportunity: the interior courtyards—already 40–50 dB quieter than the edges—serve as natural acoustic refuges that could be amplified through modest design changes. These quieter zones can become anchors for “positive soundscape” planning—locations where restorative elements (plantings, water features, acoustic art) will be most perceptually effective.

Quietest zones and periods:

- Points 4 (Park Ten) and Point 10 (children's playground) during morning and night ($\approx$ 40–45 dB).
- Points 5 (central green area) and Point 9 (interior courtyard) throughout the day (minima < 50 dB).

Loudest zones and periods:

- Points 1 (Vojvođanska & Gandijeva) and Point 3 (Vojvođanska & Nehruova) in the afternoon (> 90 dB).
- Points 2 (parking area and basketball court) and Point 7 (Japanska & Nehruova) during daytime and afternoon (80–95 dB); nighttime levels fall to 60–65 dB.

CONCLUSION

Using the measurement methodology described, this paper has so far presented only a subset of the findings. A more comprehensive analysis could be achieved by: first, generating geospatial heatmaps to visualise the spatial distribution of noise levels across all ten zones—this would immediately highlight priority areas for acoustic intervention by mapping the gradient from traffic-exposed edges to quieter courtyards. Second, constructing Bland–Altman plots to quantify bias and limits of agreement between the phonometer and smartphone app—these diagrams would reveal systematic discrepancies and guide calibration decisions. Third, producing box plots for each zone to summarise median values, interquartile ranges and outliers—offering a clear comparison of variability and extreme readings across different spaces. Fourth, plotting time-series line graphs to trace diurnal fluctuations over the four measurement intervals—thereby exposing peak noise periods and temporal

patterns crucial for scheduling interventions. Finally, performing spectral analysis to compare the frequency characteristics of sounds recorded at perimeter intersections versus interior communal areas—illuminating not just “how loud” but “what type” of noise dominates in each context. Together, these systematic visualisations would deliver a multidimensional understanding of the spatial, temporal and instrument-specific dynamics of New Belgrade’s soundscape.

Additionally, it needs to be stated that this is a pilot study, therefore it has some limitations that affect how broadly its findings can be applied. First, with only ten measurement points within a single residential block, so the results offer only an initial snapshot of New Belgrade’s sound environment because other blocks may exhibit different noise patterns. Second, factors such as temperature, vegetation cover and traffic intensity vary by season, so data collected in one season cannot represent year-round conditions. Given these constraints, the results should be considered preliminary indicators rather than definitive conclusions. Future research should expand spatial coverage to multiple blocks and repeat measurements across different seasons to capture temporal variability. Incorporating perceptual assessment—guided soundwalks and resident surveys—will connect objective decibel readings with human experience, identifying which acoustic features are most relevant to inhabitants.

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