Noise Levels In Medieval Towns In Transylvania. Case Study: Bistrița

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Abstract:
In the context of contemporary concerns about the quality of the urban environment, this research investigates noise levels in medieval towns in Transylvania, with a case study applied in Bistrița. The main aim is to assess the current noise impact in historic areas in relation to the inherited urban structure and contemporary social dynamics. The methodology included acoustic field measurements taken with a class II sound level meter in different time intervals and functional areas, followed by data processing in MATLAB and spatial representation using dbmaps. The results indicate significant variations in noise levels depending on the type of urban activities, with high values in commercial and transit areas, even in the protected perimeter of the historic centre. Analysis reveals an antagonism between the preservation of heritage and the noise pressures associated with tourism, traffic, and social activities, indicating an emerging need for regulations tailored to the local context. The research advances a multifaceted awareness of the medieval city soundscape in our times by theorising an integrated approach of urban geography, environmental acoustics and sustainable urban planning with direct quality of life and historic area protection policy implications.
Keywords: *urban noise, medieval town, environmental acoustics, social dimension of acoustics, Bistrița*

1. Introduction

The ”urban quality of life” has, in fact, come to the forefront of concern in the geographic, urban planning and environmental science fields in recent decades, mirroring a change in thinking from quantitative growth of cities to qualitative growth, focusing on the well-being of urban residents and the sustainability of the constructed environment. Among the aspects that directly affect the urban life quality perception, there is noise pollution, a plague that is too often underestimated in city design, and with tremendous impact on body and mind, on social interaction, and on the value of age-old architectural solutions (Goines & Hagler, 2007; Murphy & King, 2014).

The medieval towns of Central and Eastern Europe, Transylvania included, stand aside; their morphology is tight, their street system adapted to the pre-modern tradition and the concentration of activities is intensified in the centre.

Even if these features bear historical and cultural importance, they could aggravate the susceptibility to modern-day noise strains such as those from touristic, road, commercial and social sources (Licitra, 2012; Kang & Schulte-Fortkamp, 2016). The study of urban noise in medieval cities is not just a technical investigation, but an interdisciplinary exploration with direct implications for heritage protection policies, sustainable planning and spatial justice. In Transylvania, cities like Bistrița boast historic centres which are preserved and included in the tourist and cultural circuit, but are subject to a permanent exposure to noise-producing activities. In this respect, the sound analysis enables the tool to evaluate whether the contemporary uses are compatible with the urban form inherited (Botteldooren et al., 2011; Aletta et al., 2016).

And even in Romania, the study of urban city acoustics is as yet in its infancy, and when it comes to medieval cities, such studies do not yet exist that correlate sound data with spatial and social practice. The study is therefore a response to this deficit, and it also forms an empirical basis for the elaboration of local regulations, adapted to the specific urban and cultural context of the Transylvanian cities.

The present research aims to investigate noise levels in the medieval city of Bistrița, using an integrated methodology combining acoustic field measurements, digital data processing and spatial representation. The main goal is to assess the noise impact in historic areas in relation to the inherited urban structure and current social dynamics. The relevance of the research lies in its ability to generate knowledge applicable in urban planning, heritage protection and local public policy formulation.

The international literature on noise in cities is extensive and covers such subjects as perception of noise (Brown & Muhar, 2004), noise mapping (Maisonneuve et al., 2010), effects of noise on health (Basner et al., 2014), as well as the integration of acoustics into the urban environment (Kang, 2007). In Europe, the Environmental Noise Directive 2002/49/EC has led to the production of noise maps and action plans to reduce noise in major cities.

In Romania, investigations are conducted on a smaller scale, focusing on larger cities and industrial or traffic noise sources (Munteanu et al., 2019). Medieval cities, except for a handful of brief investigations conducted in Sibiu or Brașov, have not received systematic attention from an acoustic angle. However, although a city renowned for the strength of its historical identity, it has no official acoustic map.

A recent research in the journal Processes MDPI presents a new way of mapping acoustic comfort at the urban scale, considering noise levels along with how residents perceive those noise levels (Zarei, F. et. al,2024). The study underlines the fact that in cities with historical heritage like Bistrița, the perception of noise is not only a matter of physical comfort, but also a cultural and identity one. There is a certain tolerance among residents for certain noise (e.g. traditional cultural or commercial activities), but there is friction when noise is deemed too loud or too intrusive or clashing with the character of the place (Zarei, F. et al,2024).

This social aspect is crucial regarding the development of local noise policies, since it entails and demands that the public is involved in the process of defining quiet areas, assessing noise impact, and prioritising actions (Zarei, F. et al,2024).

In the case of Bistrița, feeding noise maps with community input might lead to better historic centre protection and to more just urban planning.

The study proposes an integrated approach based on three pillars: urban geography, environmental acoustics and sustainable planning. By using a Class II sound level meter and measuring at different time intervals, and then processing the data in MATLAB (Tătar,2025), the research provides a detailed picture of the spatial distribution of noise. The dbmaps representation allows the visualisation of noise differences between commercial, residential and transit areas, highlighting the tensions between functionality and heritage protection (Murphy & King, 2016; Aletta et al., 2018).

The main hypothesis is that the historic areas of Bistrița, although formally protected, are exposed to high noise levels, incompatible with their cultural and touristic function. It is assumed that commercial activities and road traffic generate significant noise pressures, and the lack of local regulations contributes to perpetuating this situation. The analysis aims to confirm these hypotheses by correlating acoustic data with the functional typology of urban spaces.

The findings show important fluctuations in noise levels by type of urban activity, with extreme values in commercial and transit areas, also including the protected perimeter of the historic centre. It reflects a tension between heritage protection, and the noise demands of tourism and urban transport. This study demonstrates the importance of specific local regulations that consider acoustics as an integral part of urban planning and the protection of quality of life in historical districts.

2. Methodology

For better organisation and coherence, the methodology has been structured as follows :

A. Study area and period

The analysis is conducted on the urban area of Bistrița municipality in the Bistrița-Năsăud County, Romania. Noise levels were monitored in field actions in the following locations: Central Square, Passages I–XIII, Ecaterina Teodoroiu Street, Albert Berger Street, Parcului Street, Dornei Street, Ion Minulescu Street, and Small Square. During the September–October period, decibel level measurements were conducted in the specified area. The noise sources identified and included in the study were: the bells of the Evangelical Church, road traffic, and commercial and craft-related activities in the Historic Centre of the city. Daytime and nighttime cumulative noise levels were determined for weekdays and weekends, at the best meteorological conditions (no wind, no rain).

B. Equipment and technical parameters

Noise was measured with the SNDWAY SW-523 sound level meter on mobile and on fixed tripods.

The instrument meets the requirements of the standards ISO 9613-2, SR 10009, SR 6161 and is a Class 2 instrument according to the IEC 61672-1 with a measurement uncertainty of 1.5 dB.

This scale of accuracy is appropriate for outdoor environmental monitoring and urban cognitive evaluations as suggested by the World Health Organisation (WHO), Directive 2002/49/EC, and Romanian Law No. 121/2019.

The calibration was done before each series of measurements, and active noise reduction was obtained with the use of high-quality headphones. (Figure 1)

Figure 1. Class 2 Sonometer used in the study

Source: Realised by the author

Other technical data for SNDWAY 523 professional sound level meter plus decibel meter (https://www.optimusat.ro/):

- The microphone is a condenser microphone.
- It has analogue inputs and outputs.
- It is resistant to dust, water and drops from a height of 1.5 meters.
- Measurement range: 30~130dBA
- Accuracy: ± 1.5dB;Resolution: 0.1dB.
- Frequency Range: 31.5HZ ~ 8KHZ;-Frequency Weighting: A
- Sampling frequency: 2 times/sec; Auto Power Off - Low Battery Indication; Max Hold function.
- Operating conditions :Temperature: 0 ~ 40 °C (32 ~ 104 °F),Humidity: 10 ~ 80% RH
- Storage conditions :Temperature: -10 ~ 60 °C (14 ~ 140 °F); Humidity: 10 ~ 70% RH.
- Power supply: 3 x AAA LR6 batteries ;Dimensions: 200 x 60 x 27 mm

C. Measurement Protocol

At all locations, background noise monitoring was carried out for 30 min (with recording every 120 seconds) to record C-weighted sound levels (dBC).

dBC was used to perform a more objective assessment of low-frequency noise sources such as diesel engines, trucks and buses, which are typically underweighted by dBA filtering.

This dual-scale approach allowed a better overall quantification of urban noise pollution, also taking into account vibrational and impact-punitive aspects. Support: Tripod for support (fixed and movable point), calibration and headphones for isolation and range sound detection.

Optimal weather conditions (no wind, rain) in 100% of the cases.

D. Data Organisation and Analysis

Individual measurements were obtained and organised into four groups (one for each thematic cluster: traffic corridors, residential areas, shopping streets and squares, and green areas). The raw data were extracted and processed with MATLAB to perform numerical analysis and spectral analysis, which included peak detection, frequency distribution and time variation. A spatial visualisation of the noise map was then created using dBmaps, which is a GIS tool for acoustic cartography. This combined approach guaranteed that the analysis was both rigorous and spatially meaningful.

Mentioned: To validate and complement the acoustic measurements made with the SNDWAY SW-523 Plus sound level meter, I used a triangular method composed of direct field observation, analysis of digital acoustic maps (dBmaps), MATLAB simulations, tripod mounting and the use of headphones for filtering ambient noise.

This integrated approach allowed comparison of recorded values with modelled estimates and contextual auditory perception, providing a comprehensive picture of the intensity and spatial distribution of urban noise. By triangulation, we reduced the risk of instrument errors and strengthened the ecological validity of the data.

3. Results

Map 1: 1.5 m Height Decibel Distribution. This map is based on refined measurements of the noise level at pedestrian level, at which point the social, touristic and commercial uses of the space generate the greatest concentration of people. The values recorded, 54.1 dB and 66.1 dB, represent relevant sound pressure in areas of transit and business, also in the area inside the walls of the historic centre. The chromatic scale points out a spontaneous acoustic zoning, with noise aggregation in the most visited locations. (Figure 2)

One distinctive feature is the bells of the Evangelical Church, which produce a localised peak in sound level with a very slow decay. While these sounds have symbolic and cultural significance, they may also result in the surpassing of thresholds of auditory comfort – particularly if occurring over multiple occasions or combined with other sources of noise. In this perspective, the bells are at once an acoustic marker of identity and a complexity factor in the analysis of the city.

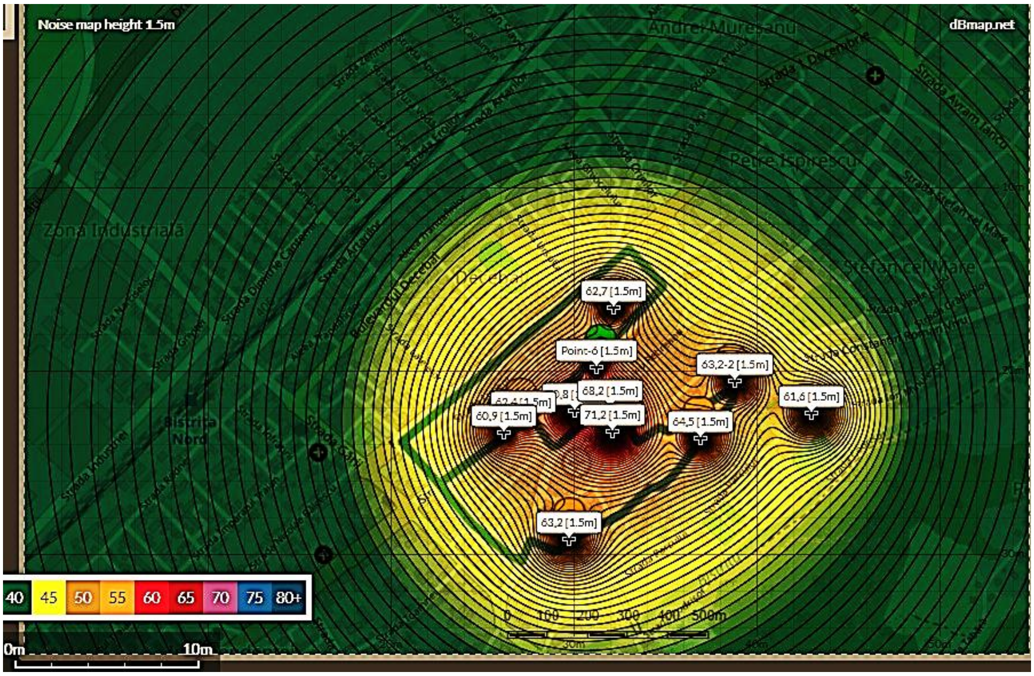

Figure 2. Maps 1 analyses
Source: Realised by the author

Map 2: Network of Measurement Points and Influence Radii (61.5 m). The second map offers a perspective on the spatial extension of sound influence within the medieval urban environment. The evenly distributed measurement points and concentric radii ranging from 100 to 500 meters enable the modelling of noise propagation according to street morphology. The blue path connects points with high pedestrian and vehicular flow potential, suggesting the existence of persistent sonic corridors. (Figure 3)

In the vicinity of the Evangelical Church, there is an overlap between the influence zones of the bells and those of traffic, which may generate acoustic interference and complicate source delineation. This area thus becomes a complex acoustic nucleus, where noise perception is shaped by both physical intensity and cultural significance.

Within the research framework, the analysed noise maps reflect longitudinal sound waves, with emphasis on low- and mid-frequency acoustic waves filtered through the dBC regime. This methodological approach allows for a more accurate assessment of urban noise sources with a vibrational component, such as heavy traffic, diesel engines, and church bells, which are underrepresented in dBA filtering.

For Map 2 (Figure 3), the spherical propagation of sound waves is distinctly noticeable, characteristic of the Evangelical Church bells—a high-altitude, airborne point source with multidirectional sound emissions. Unlike road traffic, which generates linear waves along street axes, the bells produce acoustic waves that radiate in all directions, including vertically and obliquely, influencing a wide area of the historic centre.

This spherical propagation is visible in the map's concentric circles, which indicate the acoustic influence zones of the bells, with gradual attenuation depending on distance. In the context of medieval morphology—with narrow streets and reflective facades—sound waves may undergo multiple reflections, generating acoustic interference and localised amplifications.

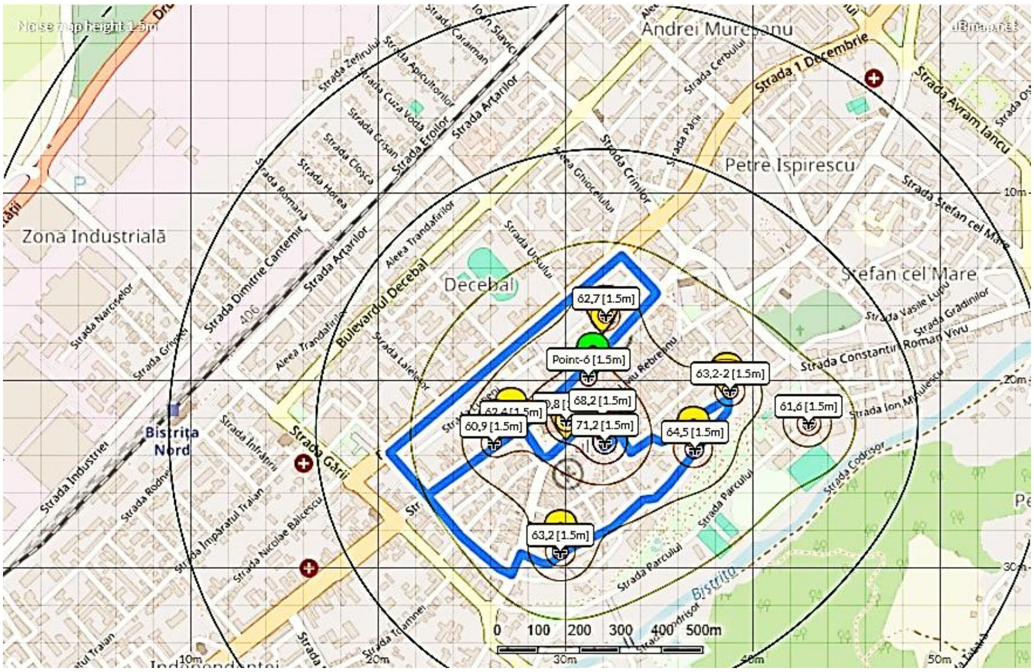

Figure 3. Maps 2 analyses
Source: Realised by the author

The acoustic waves generated by historical church bells propagate spherically from elevated point sources, influencing not only the immediate surroundings but also distant urban areas due to their multidirectional emission and interaction with built morphology. In medieval cities, narrow streets and reflective facades amplify these effects, creating zones of acoustic interference and prolonged reverberation (Nastri & Todisco, 2025).

Evangelical Church in Bistrița: the bells are raised to a high point type aerial acoustic source, which promotes a spherical sound wave propagation. This type of emission presents a sound propagation in all directions at a horizontal, vertical and oblique angle with a progressive attenuation considered distance and architectural barriers. Tirpeș notes that the effect of wave reflection is important, and this effect can cause special sound effects in the streets, bumps of sound and can be superimposed over other sound sources, such as road traffic, in a medieval city with narrow streets and reflective façades like Bistrița.

This spherical propagation is confirmed by the spherical propagation in the acoustic impact map, showing the impact areas of the sound of the bells represented by concentric circles during the study.

Unlike the linear noise of traffic, which is contained by the axes of the streets, the sound of the bells is volumetric, reaching areas that are not accessible to visual control.

And this has implications not just for acoustic studies but for city planning too, since it contributes to the creation of spaces where good auditory comfort and the symbolic meaning of space can be enhanced.

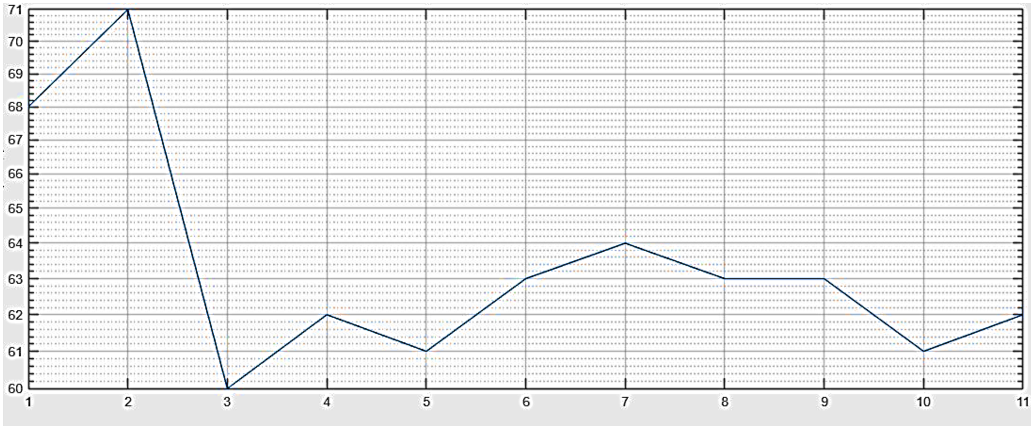

Figure 4. Line graph data analyses
Source:https://www.mathworks.com/

The chart shows the changes in the sound level (dB) at each of the 11 points (x = 1–11) with the sound pressure level reaching a local maximum at x = 2 (approximately 71 dB) then dropping significantly at x = 3 (approximately 61 dB) and leveling off between 61 and 64 dB for the rest of the points. (Figure4)

The acoustic maximum at x = 2 corresponds to a key area in a noise exposure sense where hearing discomfort and functional-heritage conflict may occur. The following attenuation, convergence and overlap imply that a kind of buffer zone or an acoustic transition zone may exist where the SPLs are equalised or normalised.

The Importance of Social Perception and Cultural Context in Assessing Urban Noise (Ahmed Mustafa Jaff et al., 2023). In the context of medieval cities such as Bistrița, acoustic analysis extends beyond technical measurements, becoming a tool for understanding the relationship between space, community, and sonic identity. The two acoustic maps developed in the study — the distribution of decibel levels at pedestrian scale and the network of sonic influence — reveal overlapping zones between symbolic sources (e.g., church bells) and functional sources (e.g., road traffic), generating complex acoustic nuclei. These zones can influence residents' perceptions of urban comfort as well as the cultural value of space. Integrating the social dimension into this analysis enables the identification of noise conflict areas and the formulation of solutions that reflect both community needs and heritage preservation. Thus, noise mapping becomes an act of spatial justice, in which the voices of residents contribute to shaping a balanced and sustainable soundscape.

4. Conclusion

The study of acoustics in medieval Bistriţa supports the general assumption: although historic areas are shielded in a legal sense, they are subjected to high noise levels that are not compatible with their cultural and touristic role. This is not speculation, but rather measurements, acoustic mapping, spectroscopy conducted with devices that are compliant to international standards (IEC 61672-1, ISO 9613-2) and analysed via MATLAB and dbmaps.In terms of its application, the study provides a sound and reproducible model for the evaluation of sound pressure in historic centres, with implications for local governments, conservation-based urban planning and public health policies..

From an applied perspective, the research offers a replicable model for assessing sound pressure in historic centres, with relevance for local administrations, conservation-oriented urban planning, and public health policies. The use of the SNDWAY SW-523 Plus sound level meter, mounted on a tripod and calibrated before each session, enabled the collection of reliable data with an uncertainty of ±1.5 dB. Dual-channel recording (dBA and dBC) allowed the identification of noise sources with vibrational components — such as diesel engines, heavy traffic, and church bells — which are often underestimated in conventional acoustic assessments. Acoustic mapping via dbmaps revealed two distinct types of sound distribution: a linear pattern associated with road traffic, and a spherical pattern generated by the bells of the Evangelical Church.

This distinction is necessary to define the zones of acoustic influence and to develop appropriate regulations for the source type. For example, spherical sources (e.g., bells) need vertical and oblique mitigation measures (such as rooftop sound barriers or acoustic curtains on building façades), while line sources can be mitigated by sound-absorbing pavements, speed controls, or traffic management.

The sound pressure level variations (Figure 4) exhibit a local maximum (~71 dB) at x=2, which is then followed by a strong attenuation. This fluctuation suggests the presence of buffer zones or acoustic transition areas, which can be leveraged in spatial planning as equilibrium perimeters between activity and noise protection. Concretely, these zones may be transformed into green spaces with sound absorption roles, pedestrian passages with controlled acoustic regimes, or interface areas between commercial and residential functions.

Moreover, the results can inform the design of tourist routes with controlled acoustic profiles. Zones with high sound pressure may be avoided or reconfigured, while those with moderate levels can be promoted as spaces for relaxation and urban contemplation. In this sense, acoustic maps become tools for tourist orientation, urban marketing, and civic education.

The study carried out in Bistriţa confirms the assertion of extreme noise exposure in historic centres and, at the same time, presents an applied model for monitoring, controlling and managing urban noise in cities of the medieval type._By including the social aspect, using a sound methodology, and suggesting specific technical measures, the work lays the foundation for sustainable acoustic urbanism — a heritage, function, and quality of life scenario.

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