REMOTE SENSING TECHNOLOGIES IN NOISE CONTROL

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Abstract

Noise pollution is a growing issue affecting people's health and well-being. This paper explores the use of remote sensing technologies in urban noise measurement and modelling. By providing detailed 3D data, these methods improve the accuracy of noise maps and address limitations of traditional approaches. Challenges include high costs and integration requirements. This paper highlights the potential of remote sensing to enhance noise control and urban planning.

Keywords

Remote sensing, noise pollution, LIDAR, noise mapping, urban acoustics

1 INTRODUCTION

As human settlements continue to grow and expand, driven by the development of transport networks and technological advancements, the problem of noise – often overlooked in urban planning – is becoming increasingly significant. This type of environmental disturbance can affect not only urban settings but also rural areas, creating challenges for both human well-being as well as ecosystems. Noise, an unwanted and disturbing sound, can lead to a variety of health problems. It is associated not only with hearing loss, tinnitus and sound hypersensitivity but also with cardiovascular diseases, sleep disturbances, stress, and cognitive impairments [1]. Thus, effective noise protection is essential.

Noise can be categorized based on its environment: workplace noise and non-workplace noise. In the workplace, protection is focused on sources related to activities performed, such as heavy machinery in factories or air conditioning in offices. These sources are primarily indoors. In non-work environments, such as residential buildings, schools or hospitals, noise sources can also be internal, including technical equipment like HVAC systems or elevators. However, outdoor noise sources, including transportation (automotive, rail and aviation), industry and construction, receive significant attention due to their impact on natural ventilation in buildings.

Various methods exist for measuring and modelling these noise sources. Professional sound analysers equipped with highly sensitive microphones are typically used for measurements. Software tools simulate noise sources for urban noise modelling and noise map creation. However, with advancements in technology, modern methods like remote sensing, which include photogrammetry and laser scanning, are becoming viable alternatives.

2 STANDARD METHODS OF URBAN MEASURING AND MODELLING

In acoustics and noise control, direct measurements often provide more reliable data than modelling and calculations. This is due to the inherent limitations of software and its inability to replicate acoustic anomalies. While models are crucial for predicting noise levels and planning mitigation strategies, they frequently oversimplify real-world scenarios. Incorporating certain factors, such as atmospheric conditions, irregular topography and variations in material absorption, accurately still remains challenging. These limitations underscore the need for complementary methods that can enhance the reliability of noise assessments, bridging the gap between theoretical calculations and on-site measurements.

Received 15/01/2025/Accepted 02/04/2025/Published 30/09/2025 DOI 10.13164/juniorstav.2025.26090

Measurements

Noise measurements involve the use of sound analysers equipped with frequency analysis capabilities, connected to sensitive microphones. These devices record ambient sound parameters, such as the equivalent sound pressure level L_{AeqT} in decibels, which represents the average noise level over a specified time.

Post-measurement processing includes filtering out irrelevant data and correcting noise levels for factors like background noise or reflections from nearby surfaces. Frequency analysis also detects tonal noise components, which are subjectively more annoying to human perception.

Measurement setups typically consist of an analyser, a microphone, a tripod, and an extension rod with a cable for increased range. An example of road traffic noise measurement is shown in Fig. 1.

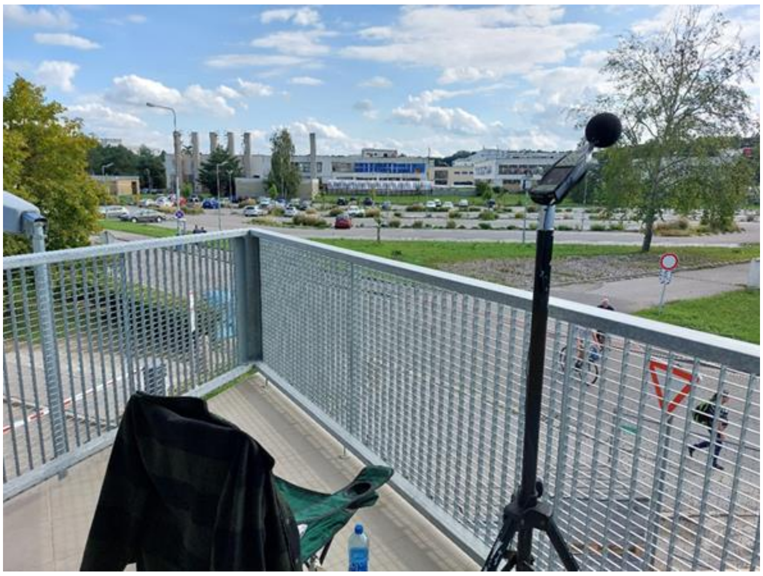

Fig. 1 Road traffic noise measurement, photo by the author.

Modelling

Urban noise modelling software relies on physical principles governing sound propagation in outdoor environments. A fundamental equation (1) describing this process is:

$$L_p = L_W + 10\log\left(\frac{Q}{4\pi r^2}\right) \quad (1)$$

where L_p is sound pressure level in dB, L_W is sound power level in dB, Q is source directivity factor, and r is distance of the source in m.

Model creation begins with designing the terrain and surrounding objects (buildings, vegetation, obstacles) using simplified shapes. For greater precision, more advanced tools can be employed as needed to process intricate geometries. When detailed drawings are unavailable or sites are inaccessible, resources like GIS, Google Maps, or satellite imagery can be used since they offer valuable data to establish a realistic baseline for the model.

Following terrain preparation, noise sources are specified with precision. Parameters for road and rail traffic, such as vehicle counts, speeds, types, and road surface conditions, are essential. Industrial zones or construction activities may also be considered where applicable. Air traffic modelling, a more intricate area, requires specialized software to incorporate variables like flight altitudes, paths, and aircraft categories. Stationary noise sources, such as machinery, are modelled using site-specific measurements or derived parameters.

The process culminates in generating a noise map that visualizes noise propagation across the studied area. These maps use colour gradients to depict varying noise levels, thus enabling intuitive interpretation. Softwares like IMMI, LimA, CadnaA, and Hluk+ are widely used, each tailored for specific needs. Fig. 2 shows a 3D noise map produced in Hluk+, showcasing the spatial distribution and intensity of urban noise.

DOI 10.13164/juniorstav.2025.26090

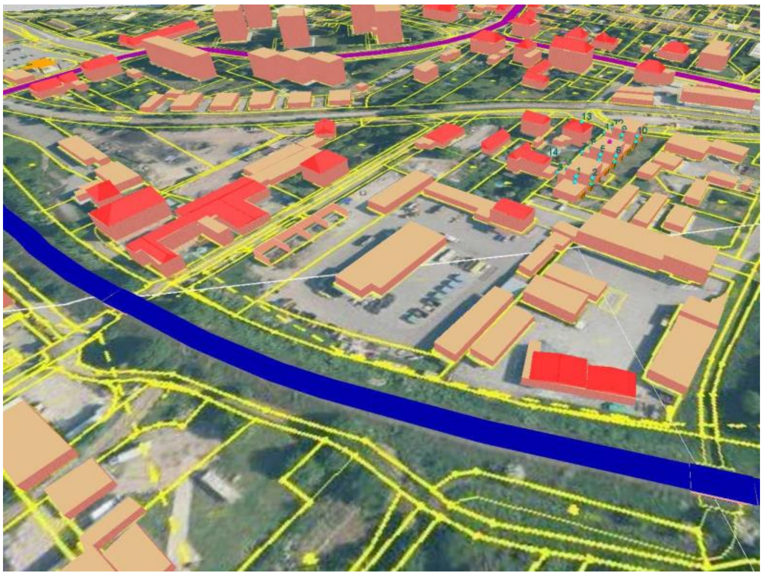

Fig. 2 3D noise map model in Hluk+ software, image by the author.

3 REMOTE SENSING – BASICS AND TYPES

Remote sensing involves measuring object properties without direct contact, using advanced equipment installed on aircraft or satellites [2]. In the context of noise control, this technology facilitates the collection of accurate spatial and environmental data over large areas. For example, remote sensing can identify noise sources and their geographical distribution, analyse the surrounding terrain, and measure urban structures that influence noise propagation. These capabilities provide a robust foundation for creating precise noise models and effective mitigation strategies, particularly in challenging environments or areas where traditional measurement methods fall short. This technology is applied across various fields, such as:

- environmental assessment and monitoring,
- non-renewable and renewable resources exploration,
- agriculture,
- meteorology,
- mapping (topography, land use, civil engineering) and more [2].

The core components of a remote sensing system are platforms, orbits, and sensors. Platforms serve as carriers for remote sensing devices and are divided into three main types based on their operational range: ground-based (up to 50 m above the Earth's surface – including ground vehicles, towers, balloons, kites, and drones), airborne (up to 50 km – such as airplanes, helicopters, and high-altitude aircraft), and spaceborne platforms (operating between 250 km and 36,000 km – including space shuttles, stations, polar, and geostationary satellites) [3].

The trajectory of a satellite, known as its orbit, varies in terms of altitude, orientation, and rotation relative to the Earth. The primary types of orbits include geostationary orbits, which remain fixed relative to a point on the Earth; polar orbits, which pass over the poles and provide global coverage; and sun-synchronous orbits, which allow for consistent lighting conditions during data collection [3].

Remote sensing is broadly categorized into two main types based on the signal source: active and passive. Active remote sensing systems use their own energy sources to illuminate the target, while passive systems rely on reflected natural energy, such as sunlight [4].

Active sensors

Active sensors emit a directed signal, such as light or electromagnetic waves, towards a target and then analyse the reflected or scattered response to extract detailed information about the object or area under observation. This process allows for highly controlled data collection, as the sensor generates its own signal, making

DOI 10.13164/juniorstav.2025.26090

it independent of external light or energy sources. As a result, active sensors can operate effectively both during the day and at night, as well as under various weather conditions, provided the signal can penetrate the atmosphere or environmental obstructions [4].

The functioning of active sensors depends on the type of emitted signal and the specific parameter being measured. For instance, some systems use radio waves to determine distances and detect objects, while others employ laser pulses to calculate elevation or map surface details. These variations enable active sensors to address a wide range of applications, from monitoring terrain and vegetation to assessing atmospheric conditions and detecting motion [4].

Examples of active remote sensing technologies include:

- radar – a sensor that determines distance using radio signals,
- LIDAR – a sensor that determines distance using light,
- laser altimeter – measures elevation with LIDAR [4].

Passive sensors

Passive sensors, on the other hand, rely on detecting naturally available energy, such as sunlight, that is either reflected by or emitted from the target. Unlike active sensors, passive systems do not generate their own signals, making them more dependent on external conditions like weather, time of day, and atmospheric clarity. This reliance means that passive sensors typically perform best under favourable weather conditions and in environments with sufficient natural illumination [4].

These sensors are particularly effective for collecting broad-spectrum data across multiple wavelengths, often using advanced multispectral or hyperspectral technologies. These technologies allow the sensors to capture detailed information in various spectral bands, enabling the analysis of material composition, surface characteristics, and environmental changes. By analysing the interaction of light with different materials, passive sensors provide critical insights into vegetation health, land cover, and atmospheric phenomena [4].

Key examples include:

- spectrometer – distinguishes and analyses spectral bands,
- radiometer – determines the power of radiation emitted by an object in particular band ranges (visible, IR, microwave),
- imaging radiometer – scans an object or a surface to reproduce the image,
- sounder – senses atmospheric conditions vertically [4].

The principle of both active and passive sensors is shown in Fig. 3.

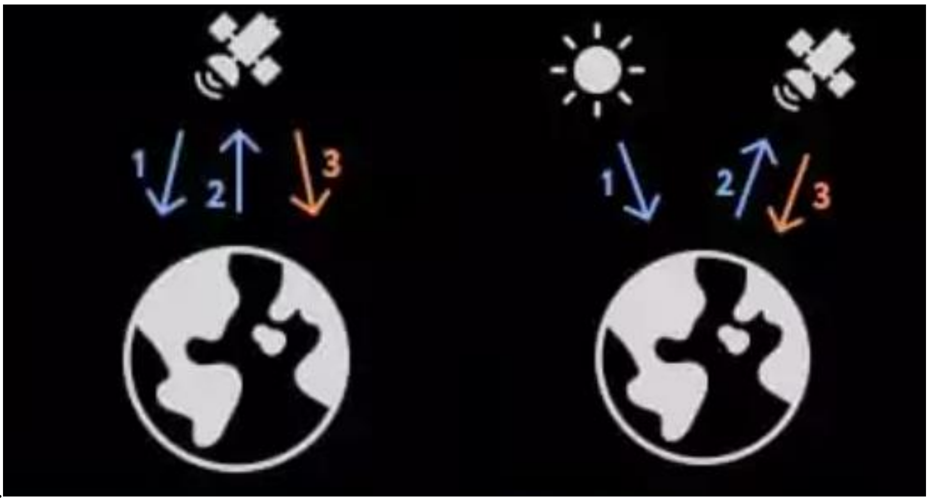

Fig. 3 Principles of active (left) and passive (right) remote sensing [4].

Application of remote sensing in noise control

Standard approaches to outdoor noise modelling (see Chapter 2) often require a variety of input data, which can lead to inaccuracies, particularly in complex or challenging terrain. To address these limitations, remote sensing technology has increasingly been utilized in recent years as a powerful tool for outdoor noise control.

For instance, in [5], LIDAR data were employed to generate detailed terrain parameters, including pathways around buildings – features typically absent from standard 2D data provided by GIS applications. Similarly, studies [6] and [7] used LIDAR-generated point clouds to create highly specific models of deciduous tree canopies, which were analysed as natural absorbers of road traffic noise. These detailed canopy models allowed for a more precise evaluation of vegetation's role in mitigating noise pollution.

In [8], LIDAR was applied for congestion monitoring by determining the surface area occupied by vehicles on roads. This data was combined with standard traffic parameters, such as volume, speed, and density, to generate enhanced noise maps which is particularly useful for locations where direct noise monitoring is rather demanding.

These case studies highlight the versatility and accuracy of remote sensing technologies in enhancing noise modelling and mitigation strategies, especially in scenarios where conventional methods do not suffice.

4 DISCUSSION

The integration of remote sensing technologies, particularly LIDAR, into urban noise measurement and modelling has introduced promising advancements in environmental acoustics. These methods address key limitations of traditional approaches, such as the lack of detailed terrain data and inaccuracies in object modelling. For instance, LIDAR's ability to generate high-resolution 3D point clouds enables a more precise representation of urban landscapes, including structures and vegetation, which play a crucial role in noise propagation.

Despite these advantages, there are still significant challenges to overcome. The high cost of acquiring and processing LIDAR data remains a major barrier to widespread adoption. Additionally, the effectiveness of remote sensing tools depends on their integration with existing noise modelling software, which may require substantial adaptations. There is also a need for further research to quantify the accuracy improvements achieved through these methods in comparison to traditional models.

Another critical aspect is the potential for remote sensing to streamline noise mapping processes in complex or inaccessible terrains. For example, urban areas with dense building configurations or natural obstacles can benefit greatly from remote sensing's comprehensive data acquisition capabilities. This can lead to more effective noise mitigation strategies, improving urban planning and public health outcomes.

Future research should focus on cost-benefit analyses, exploring ways to reduce the financial burden of these technologies while maximizing their utility. Collaboration between technology developers, urban planners, and environmental scientists will be essential in realizing the full potential of remote sensing for noise control.

5 CONCLUSION

Noise in outdoor environments can have negative effects on human health, including stress, sleep disturbances, and cardiovascular issues. As such, significant noise sources like road and rail traffic must be measured or modelled to ensure adequate comfort levels for nearby occupants.

Traditional modelling methods involve the labour-intensive creation of noise maps, typically using 2D input data from GIS applications. However, these inputs are not always accurate enough and often require on-site verification to identify missing parameters, such as detailed terrain features or nearby structures.

Remote sensing technology offers promising applications for enhancing noise mapping, such as providing detailed topographical and spatial data. It holds potential for creating complete noise maps more quickly and efficiently in the future. Still, its adoption depends on balancing its effectiveness against the relatively high acquisition costs.

DOI 10.13164/juniorstav.2025.26090

Acknowledgements

This paper was produced with the financial support of the project FAST-S-24-8620 “Digitální fabrikace v pozemním stavitelství s využitím technologie 3D tisku a digitálních dvojčat”.

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