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Noise footprint of tourist accommodations: a novel approach towards soundscape quality assessment

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Abstract. Environmental noise is a global problem with multiscale consequences, affecting human well-being, environmental health and business efficiency. Several tourist accommodations aiming towards a more competitive and profitable business, produce the by-product of noise thus resulting in a higher noise footprint. The aim of this research is to propose an approach towards the assessment and calculation of the noise footprint of tourist accommodations. Three tourist accommodations located in Lesbos Island (North Aegean Greece) were studied. The transportational, functional, natural and recreational sound sources were assessed. Furthermore, the degree of background noise was included. Noise measurements were conducted using a calibrated sound level meter. The equivalent continuous sound level (L_{eq}) noise indicator levels for each type of source were obtained and analyzed. In order to assess the overall noise footprint a composite indicator based on the signal to noise ratio was shaped. Furthermore, noise maps were created in order to visualize the noise footprint extent of the hotels studied. The main findings of this research highlighted the seasonality of the resulting noise footprint. The promotion of natural and recreational sound sources contributes towards the new concept of net-zero noise and supports quiet and sustainable tourist accommodations.

Keywords: Noise footprint; Net-zero noise; Noise map

1. Introduction

Circular economy and bioeconomy [1] action plans, reduce pressure on natural resources and promote environmental and social well-being [2]. The success of such a transition, requires a multi-level willingness from each country, and the promotion of entrepreneurial and innovative business initiatives [3]. Tourism is a global economic sector with an increased environmental footprint [4] including noise pollution [5]. Amongst the sub-sectors of tourism, tourist accommodations present a high energy consumption footprint [6]. Initiatives similar to the United Nations World Tourism Organization (UNWTO) [7] shifted the focus of tourism towards biodiversity conservation and hotel energy solutions promoting sustainable tourism [8]. Therefore, nature-based solutions in the tourism industry and the promotion of green hotels [9] has become a necessity.

A sustainable tourism model, can be improved through the promotion of soundscape preservation [10]. Both, the natural and cultural aspects of a soundscape are integral parts of its heritage [11] and their protection contributes towards acoustic sustainability. Sound is directly associated with ecological [12] and cultural [13] integrity and as a result, natural and healthy soundscapes are highly appreciated in nature-based tourism [14]. Subsequently, noise control action plans and the creation of regenerative and quiet soundscapes shaped under a sustainable and circular framework, are necessary steps towards the reduction of the noise footprint. The tourism industry encompasses various interconnected sectors such as transportation, lodging, and entertainment, which collectively have a significant impact on the environment. Similar to the ecological, carbon, and water footprint, the noise footprint model can reflect the pressure exerted by tourism activities. Hotels, which offer transportation, lodging, and entertainment services, present a prime opportunity to assess noise footprint. However, evaluating the noise impact of tourism facilities is a complex issue that can be better understood and addressed by leveraging the tools and expertise provided by acoustic and soundscape ecology principles.

The assessment of tourist accommodations acoustic environments and soundscapes can be accomplished by measuring their noise footprint and continuously monitoring them in order to attain a state of net zero noise. The concept of net zero emissions serves as a framework for taking climate action and striving to stabilize global temperatures. Achieving net zero entails establishing a balanced state that can be sustained for many decades while also meeting additional environmental and social benchmarks [15]. Similarly, the concept of net zero noise

can be used as a framework for the creation of healthy and quiet acoustic environments, in which the sound sources co-exist in balance.

Hotels incorporate various equipment and facilities that generate noise as part of their operational requirements. However, hotel establishments also have the potential to provide an enjoyable soundscape, promoting sustainable tourism and acoustic sustainability. This study focuses on examining the acoustic environment of a prevalent form of tourist accommodation found in Mediterranean island regions. The primary objective of this research is to evaluate the noise impact produced by three resort hotels situated on Lesvos Island in multiple seasons. A novel noise footprint composite indicator will be utilized to assess and monitor the hotel soundscape quality.

2. Methods

2.1. Case study area

For this research the acoustic environment of three resort [16] and apartment type of tourist accommodations was assessed. As it can be seen in figure 1, The hotels are located near the town of Kalloni which is a small town in the west-central part of Lesbos Island (North Aegean, Greece). On-site noise level measurements were conducted for a three-month period during the summer and autumn of 2022 (August – September – October).

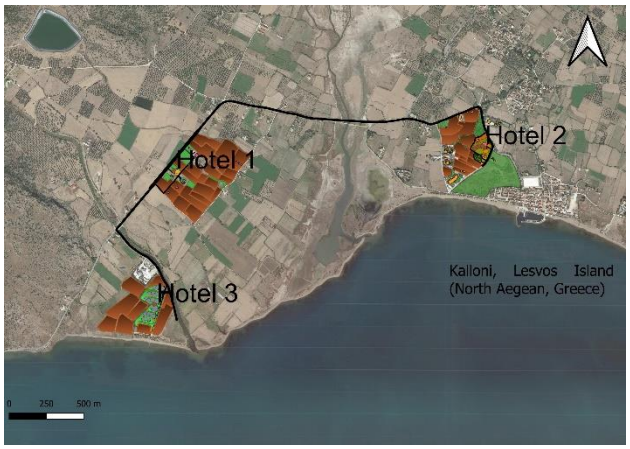

Figure 1. Case study area, the hotels in Kalloni (Lesvos)

2.2. Sound source categorization, measurement and noise mapping

The sound sources available in tourist accommodation were classified in four major categories. As can be seen in table 1, the major categories involved the functional, the transportational, the natural and recreational sound sources present in a hotel. A fifth category was included concerning the background noise levels propagating outside of the hotel premises. For each of the major categories, specific sound sources were identified (table 1).

Table 1. List of sound source category and specific sound source. A fifth category was included regarding background noise, outside the hotel premises.

Source Category	Specific Source
Functional	Air-condition units
	Water pressure valves
	HVAC systems
	Garage doors
	Lawn mowers
	Pool pumps
	Sprinklers
	Kitchen ventilation
Natural	Birds
	Cicadas - Insects
	Water sounds
	Geophonies
Recreational	Pools
	Music
	People
Transportational	Cars
	Two-wheelers
	Parking lots

All sound sources were assessed through on-site noise level measurements. The measurements were conducted using 5-minute samplings facing the sound source, at a height of 1,5 meters above ground level. The 01dB Fusion class 1 smart noise monitor, accompanied by the GRAS 40AE free field microphone were used in order to collect noise measurement data. The device was calibrated prior to data collection using a calibrator as required for all Class 1 measuring instruments and in accordance with the specifications of EN61326-1:1997+A1:1998. Data regarding the equivalent continuous sound level (L_{eq}, dBA) was processed using the dBTrait v. 6.3.0 software. The background noise levels that mainly consisted of road traffic noise were assessed using the guidelines provided by the CNOSSOS-EU road traffic noise model [17].

Topographical and structural data of the hotels were gathered. More specifically, information regarding the following urban morphology characteristics were collected and later visualized in QGiS v. 3.22.1 and CadnaA software:

- Detailed cartographic representation of the area under consideration (buildings, roads, vegetation)
- Building height and location
- Vegetation height and location
- Road type classification (Motorway, Ordinary Road, Local)
- Road surface type
- Sound source location and height

As it can be seen in figure 2, the building information gathered where visualized in 3D.

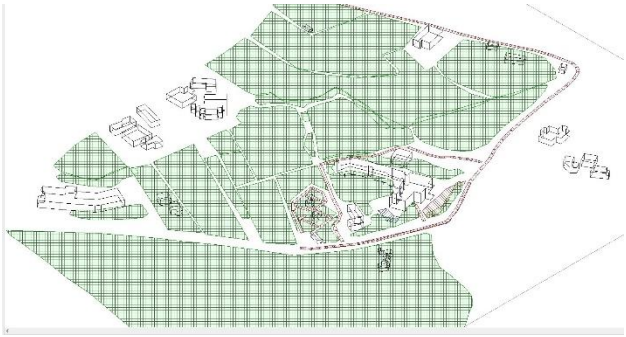

Figure 2. 3D visualization of the case study area

All the above data were incorporated in the CadnaA noise prediction software in order to produce noise maps. More specifically, isobel noise maps (a.k.a. isopleth maps) were created. An isobel map shows variations in sound pressure over a given area by connecting points in which the measured levels are equal [18].

2.3. The Soundscape Quality Index (SQI)

In order to highlight the noise footprint of tourist accommodations a composite indicator was shaped. The Soundscape Quality Index (SQI) was designed in order to include all the sound source categories mentioned in table 1. The total L_{eq} levels of each specific sound source was calculated using the formula:

$$L_{total} = 10 * log_{10}\left(10^{\frac{L1}{10}} + 10^{\frac{L2}{10}} + 10^{\frac{L3}{10}} + \cdots\right)$$

Where:

L_{total} = Each sound source category e.g. $L_{functional}$

L1, L2 L3.. = Each specific sound source of the category

Following the calculation of the total value of each sound source category, a Signal to Noise Ratio (S/N) approach was followed in order to combine the available sound sources. The total values of the natural and recreational sound sources were assessed as Signals. Furthermore, the total values of the functional, transportational and background noise values were assessed as Noise.

In order to provide a scale of comparison and shape the Soundscape Quality Index (SQI), a normalized difference composite indicator was developed. More specifically, the SQI was calculated using the formula bellow:

$$SQI = \frac{Signal - Noise}{Signal + Noise}$$

Where:

Signal = the summed values of the recreational and natural sound sources

Noise = the summed values of the transportational, functional and background noise level sound sources

The SQI measures the hotel soundscape on a scale ranging from -1 to +1, with negative SQI values indicating a lower auditory quality.

3. Results

As it can be seen in figures 3, 4 and 5, noise maps were shaped in order to visualize the variations of the noise footprint. According to the results, the noise footprint of the tourist accommodation presents a gradual seasonal decrease. This is due to the reduction in residents using the facilities.

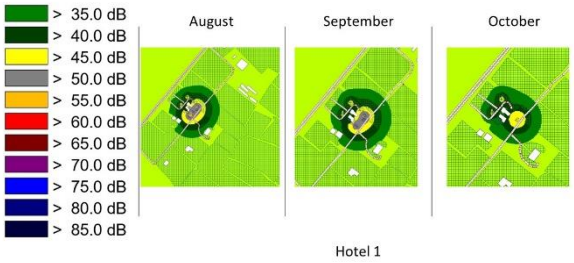

Figure 3. Noise maps for hotel 1.

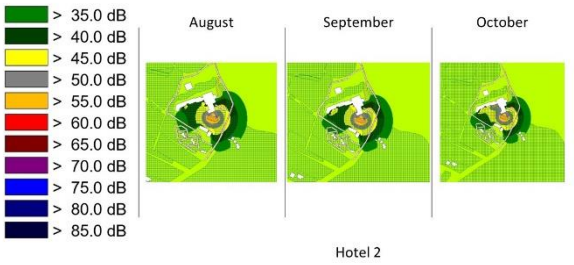

Figure 4. Noise maps for hotel 2.

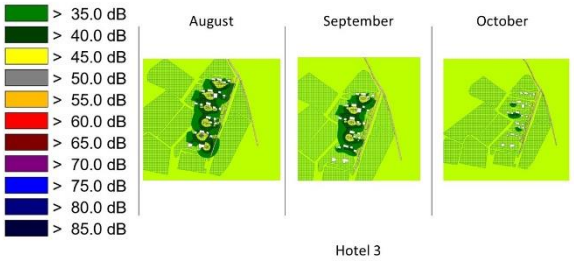

Figure 5. Noise maps for hotel 3.

In figure 6, the results from the Soundscape Quality Index calculations are presented.

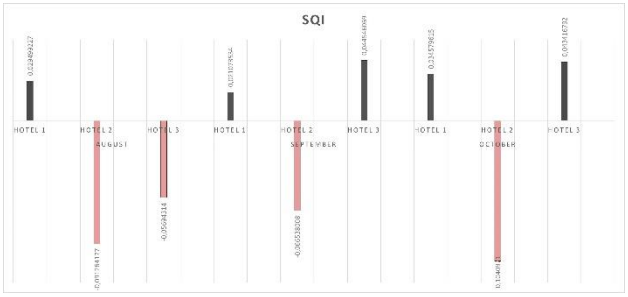

Figure 6. Soundscape Quality Index results.

The smaller sized tourist accommodation (Hotel 1) presents a steady positive Soundscape Quality Index level. This is due not only to it's size, but also due to the limited functional sound sources present. Hotels 2 and 3, present fluctuations regarding their SQI levels, due to the decrease in tourists using the hotel facilities.

4. Conclusions

The findings demonstrate a decrease in the noise footprint from August to October, primarily influenced by factors such as hotel size, visitor count, and reduced hotel occupancy. Moreover, the developed SQI effectively captures and highlights the overall sound quality of the hotels, showing improvement as the months progress.

Furthermore, this research highlights the potential of circular economy actions in enhancing the soundscape quality of hotels. By implementing sustainable practices and resource-efficient measures, hotels can contribute to a more pleasant auditory experience for guests. Additionally, the SQI index holds promise as a valuable tool for monitoring hotel quality and serving as an indicator of quiet tourism. Finally, the efforts to balance the SQI index requires a series of sound source replacements. More specifically, efforts to increase natural and recreational sounds result in a positive SQI index, a more pleasurable soundscape and therefore, a net-zero noise state. Overall, this study sheds light on the relationship between noise footprint and the impact of circular economy actions, emphasizing the significance of promoting soundscapes that foster tranquility and enhance the overall quality of hotel experiences.

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