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Circularity-driven urban quietness as an indicator of sustainability

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ABSTRACT

The concepts of noise and quietness are multidimensional, contradictive and retain a degree of fuzziness. Their notion expands between the physical dimension of sound to a phenomenological/perceptual construct. The perception of noise as a sound of high-intensity or as an unwanted sound has shaped the concept of quietness as an urban sound design goal overlooking ecological co-benefits. The main purpose of this research is to highlight the symbiotic relationship between urban quietness and sustainability. More specifically, actions of circular urban development, including green walls and electromobility were modeled, to highlight their effect on the sound environment of a Mediterranean coastal medium-sized city. Following the guidelines provided by the CNOSSOS-EU road traffic noise model, the effects of the aforementioned sustainability actions were visualized by means of noise mapping. The results indicate that a noise level reduction of approximately 4 dB(A) could derive with the implementation of circular urban development measures.

1. INTRODUCTION

The statement that something, or someone, or an area is quiet is vague and retains a degree of fuzziness. The intermediate stages of quietness, and the lack of an absolute state of silence, support this uncertainty. Nevertheless, quietness is an important factor of environmental health and the existence of quiet areas in an urban environment is crucial. The above need is intensified due to the increasing urban population [1]. The pursuit of quietness begins with how it is defined and culminates in the question of whether it is an environmental condition that can be created and planned by us, or an environmental/ecological trait that can be re-emerged, despite of us. The polysemy of the concept of noise and the variety of characterizations attributed to this term has determined the interpretation of quietness in an analogous manner as a counterpoint. If noise is interpreted as a sound of high intensity characterized by a high decibel value [2], then quietness is the opposite. It is a fact that the noise levels of a sound environment can be measured using a noise level meter. This information alone can be used in order to describe a specific part of the area's sonic identity and determine whether this area is quiet or not. Nevertheless, specific knowledge lacks in context, homogenizing all sounds under the prism of their intensity. A different approach requires the perception of noise as an unwanted sound, rendering quietness as a desirable acoustic condition and thus a positive or pleasant soundscape. The approaches dealing with the two differentiating objectives are the soundscape approach [3] and noise control approach [4]. These two approaches and the general ambiguity in the conceptualization of the terms has caused the creation of different urban acoustic design methodologies with different results, which often overlook ecological co-benefits. The main goal of this research is to assess the sustainability actions in an urban environment that could result to a state of quietness. For this reason, the paradigm of urban circular development and green infrastructure will be assessed. More specifically, the circular economy actions of green walls and electromobility were modeled in order to verify the acoustic benefits in a Mediterranean urban sound environment.

2. BACKGROUND

The noise control approach aims at reducing noise levels from various sources that can be measured, predicted and addressed [5]. Through the noise control approach, quiet

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areas are perceived as acoustic environments with low noise dB(A) levels. Therefore, a range of 50–55 dB(A) is suggested [6]. The conceptual limitations of the terms "noise" and "quiet" and their interpretation as a contradiction have initiated design tactics with reduced ecological co-benefits, promoting the short-term benefits of pleasant soundscapes. The association of quietness with biodiversity [7] presents an opportunity for long-term ecological urban planning and design. In this manner quietness can become the means towards a truly sustainable city. The circular economy model and the urban circular development actions similar to green walls and the introduction of electric vehicles (EVs) could aid towards the creation of a quieter urban environment.

Circularity, contradicts the so-far "take-make-waste" linear model and encourages a restorative and regenerative model, promoting amongst other actions resource looping [8]. Urban circular economy refers to a regenerative system in which resource input and energy leakage are minimized by closing material and energy loops [9].

Amongst the most important factors towards an urban city's circular transition are a) resource looping incorporating reuse and recycling systems similar to grey water re-purposing, b) ecological regeneration that involves the promotion of the natural cycles, c) the optimization of the energy production towards local and renewable methods, d) the upgrading of buildings, with including green walls and green rooftops and finally, e) the mobility systems that are compatible with a more sustainable way of commuting [10]. The circular economy model and the encouragement towards resource looping, can minimize waste and set the ground for a truly sustainable urban environment.

Greening systems, such as green walls, living walls, and green roofs, offer a range of benefits to buildings and their occupants and to the overall urban environment. Furthermore, they contribute to indoor air quality and can enhance residents' well-being by providing a visually appealing and biophilic environment. [11]. The absorption of sound waves is influenced by the porosity of the material they enter. As the sound waves travel through the pores of the material, friction occurs between the air molecules and the pore walls. This friction leads to the conversion of sound energy into thermal energy, causing the sound waves to be absorbed by the material [12]. Electric vehicles (EV), compared to conventional internal combustion engine vehicles (ICEV), could aid towards the reduction of environmental pressures [13] and contribute towards a more sustainable urban transport system. Electric vehicles play a significant role in the circular city economy paradigm [14] and offer various co-benefits, including reducing noise levels [15]. When compared directly to conventional vehicles, EVs can have a noise level difference of up to 6 dB(A) [16]. However, it has been observed that above a speed of 40 km/h, the noise difference between EVs and internal combustion engine vehicles (ICEVs) diminishes. This is because the rolling noise generated by tire-road friction tends to mask other types of sounds, thereby reducing the perceived difference in noise levels.

3. METHODS

For this research the case study area was located in the center of the city of Mytilene (Lesvos Island, North Aegean, Greece). Mytilene is a medium-sized Mediterranean city located in the island of Lesbos (North Aegean, Greece). For the specific research, a small, urbanized area located in the city center of Mytilene was assessed (Figure 1).

Figure 1. The case study area located in the city of Mytilene (Lesvos Island, North Aegean, Greece).

For assessing the noise conditions of the specific case study area, the guidelines provided by the CNOSSOS-EU road traffic noise model, were implemented [21]. The data regarding the equivalent continuous sound level (Leq, dBA), along with the simultaneous traffic counts, were collected for a 10-day period and later averaged, during the summer of 2022 (25/07/2022 – 10/08/2022) avoiding weekends. Topographical data regarding the position and height of the nearby buildings were also gathered. noise level measurements were conducted in ten (10) noise monitoring checkpoints. The check points had a distance of 50 meters from each other, and each 10-minute measurement was conducted at a height of 1,5 meters above ground level during the day period. For this research, the sound absorption coefficient of the area's facades was increased to a degree of $\alpha = 0.40$ for the 1/3 octave spectrum. To simulate the introduction of EV's on the specific area's road network of the area, correction coefficients on the noise levels of the light vehicles counted, were implemented. For this research the correction coefficients for the propulsion noise of EVs have been implemented for the light vehicles that were counted. Finally, the statistical differences of the measured and simulated noise levels (Leq dB(A)), using the SPSS software (IBM SPSS Statistics, Version 28.0.1.0) were assessed.

4. RESULTS

A total of 10584 vehicles were counted during the 10-day sampling period. As it was expected the light vehicle category presented the highest quantity of all vehicles reaching 76% of the total vehicles. Unsurprisingly, mopeds were the second most used vehicle (14.3%), which is typical for a Mediterranean island. The measured noise levels present slight fluctuations for every recording day, with levels being above the suggested by WHO 55 dB(A) levels. By incorporating circular actions in the simulation procedure and more specifically, by introducing green walls and EVs, the simulation was executed once more. As seen in figure 2, the dB(A) results resulted by the introduction of circular economy actions, still present high noise levels above WHO's recommendations. The measured and simulated noise levels at the 10 checkpoints/receiver points were statistically compared. A paired samples t-test was carried out in order to identify whether there were significant differences amongst the measured and simulated noise levels. The results for the measured noise levels, in relation to the calculated noise levels with the introduction of circular development actions, differ significantly: $t(10) = 5.820$, $p = < 0.001$, with an effect size of $D = 2.700$ and a mean difference of 4.17 dB(A).

5. CONCLUSIONS

Based on the information provided, the combination of electric vehicles (EVs) and green walls has been found to be a promising solution for creating a healthy urban sound environment. The simulation results indicate that a combination of circularity measures, such as EVs and green walls, can help alleviate the burden of environmental noise. However, it is noted that the challenge lies in transitioning from pilot projects and experimental work to implementing real changes in urban environments. The goal is to develop a frugal, resilient, and welcoming city with a high-quality sound environment. This implies the need for a shift towards sustainable and innovative approaches in urban planning and design.

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