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Noise in the outdoor areas of a University Hospital: a survey method

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Abstract

Noise in hospitals can significantly affect patients and healthcare staff, disrupting physiological processes and contributing to stress, annoyance, and reduced well-being. Although indoor hospital acoustics have been widely investigated, the acoustics of outdoor healthcare spaces remain under-explored, despite their potential to support healing environments. As part of a three-year project, the acoustic environment of Sant'Orsola University Hospital in Bologna, Italy, is being investigated. An integrated methodology combined acoustic monitoring, numerical modelling, and two participatory soundwalks conducted in accordance with ISO 12913-2. Forty-two participants assessed locations using validated Italian soundscape descriptors. Results show a soundscape characterized by anthropogenic sources, particularly internal traffic, service vehicles, ambulances and construction activities, whereas natural sounds are limited to courtyards, green areas, and locations near water features. The Circumplex Model establishes baselines for ISO pleasantness and ISO eventfulness. This supports defining target values and evaluating whether design interventions move the soundscape towards the desired perceived state. This study demonstrates how integrating perceptual and physical data can support the identification of critical areas and inform human-centred design strategies. By emphasising the importance of considering the soundscape from the earliest planning stages, these findings contribute to the development of multidisciplinary guidelines to improve the restorative and supportive outdoor environments for healthcare.

Keywords: *noise in hospitals, soundscape, noise modelling, soundwalk, healthcare design.*

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1. Introduction

Among the environmental stressors affecting urban and healthcare settings, noise is particularly relevant. The World Health Organization identifies environmental noise as one of the major environmental risks to health in Europe, second only to air pollution [1]. Prolonged exposure is associated with annoyance, sleep disturbance, stress responses, cardiovascular effects, and reduced psychological well-being [2,3]. These effects are critical in hospitals, where patients may be more vulnerable to environmental stressors and healthcare staff work in conditions that require concentration, communication, and rapid decision-making. Research on hospital acoustics has primarily focused on indoor environments, including wards, intensive care units, maternity rooms, operating areas, and circulation spaces. Outdoor spaces in healthcare facilities remain comparatively underexplored, although courtyards, gardens, entrances, waiting areas, and pedestrian routes can influence orientation, social interaction, stress recovery, and the quality of the care experience [4]. Traditional level-based indicators are essential for exposure assessment, but they do not fully capture how users perceive acoustic environments. Soundscape, according to ISO 12913-1, is defined as the acoustic environment that a person perceives, experiences, or understands in context [5]. This shifts the assessment from sound levels alone to the relationships among sound sources, spatial configuration, activity, expectations, and subjective response [5,6].

The study is part of a three-year project with a multidisciplinary approach to the urban regeneration of the Sant'Orsola Hospital area. The wider project combines acoustics, landscape design, microclimate, lighting, visual quality, olfactory perception, accessibility, orientation, and perceived safety. In this context, soundwalks have proved to be an effective tool for perceptual assessment, complementing acoustic measurements and numerical modelling, and enabling the analysis of new design proposals for the outdoor spaces within the hospital area.

2. Method

2.1 Case study

Sant'Orsola University Hospital is one of the main healthcare complexes in Bologna, Italy, and represents a large hospital embedded in a consolidated urban context. Located immediately outside the historic city walls, the campus spans more than 7 ha and includes 32 pavilions for healthcare, teaching, training, and research activities. Its historical development, originally linked to two monastic complexes and later absorbed by the expanding city, has produced a fragmented structure of buildings, courtyards, internal roads, service areas, and residual open spaces.

The campus can be interpreted as a small city within the city. Approximately 20,000 people, including patients, visitors, healthcare professionals, technical staff, students, and researchers, move through the area every day. The site is bordered by major traffic corridors, particularly Via Massarenti and Viale Ercolani. Public transport runs along the perimeter, while internal roads are used by ambulances, logistics and service vehicles, taxis, shuttles, private vehicles, and authorized traffic. Temporary construction sites further modify the acoustic environment. These conditions make the campus a relevant case for investigating how acoustic exposure, spatial organization, and user perception interact in a sensitive healthcare setting.

2.2 Assessment Data

The outdoor acoustic environment was investigated using sound-level measurements and numerical modelling. Monitoring campaigns were carried out over approximately one year and included short-term daytime measurements and long-term monitoring to capture the spatial and temporal variability resulting from traffic flows, emergency movements, logistical operations, and construction activities. The measured data were used to develop and validate a three-dimensional acoustic model of the entire hospital campus in CadnaA. While numerical modelling is an effective tool for supporting and validating design decisions in acoustics, integration with perceptual analysis is essential in complex and sensitive contexts such as hospitals. Two soundwalk campaigns were conducted to evaluate the perceived acoustic quality of selected outdoor areas, following the Method A and B of ISO 12913-2. The first soundwalk involved 21 participants, mainly students and designers engaged in the regeneration project (48% women, 52% men; mean age 30.5 years). The second campaign was conducted approximately ten months later with 21 participants, including hospital technical staff (78% women, 22% men; mean age 38 years). The inclusion of users with different relationships to the site broadened the range of perspectives represented in the assessment. The questionnaire addressed perceived sound-source dominance, perceived affective quality, overall evaluation, and appropriateness, using the validated Italian translation of the ISO soundscape descriptors [8]. Pleasantness and Eventfulness scores were calculated according to ISO 12913-3 [9] and represented in the circumplex model derived from Axelsson et al., following recommendations for quantitative soundscape data representation [10,11].

3. Results and Discussion

The two soundwalk campaigns show that the outdoor acoustic environment at Sant'Orsola University Hospital is characterised by multiple, temporally variable sound sources. Anthropogenic sounds dominate most locations, particularly internal road traffic, service vehicles, ambulances, construction activities, mechanical equipment, and human voices. Natural sounds are less frequently perceived and are mainly associated with specific courtyards, green areas, chirping, and water features. The acoustic model, in Figure 1, confirms and spatially extends this evidence: along the principal internal road axis, daytime levels reach approximately 60 dB(A) in the most exposed areas. This result demonstrates that the hospital sound environment is not determined solely by external urban traffic, as internal mobility represents a major contributor to site-wide exposure. Ambulances, taxis, private vehicles, service vehicles, and logistical movements are concentrated along a limited number of routes, generating both continuous background traffic and salient events. Consequently, critical conditions occur along façades, pedestrian paths, waiting areas, and open spaces, including locations relatively distant from the surrounding urban roads.

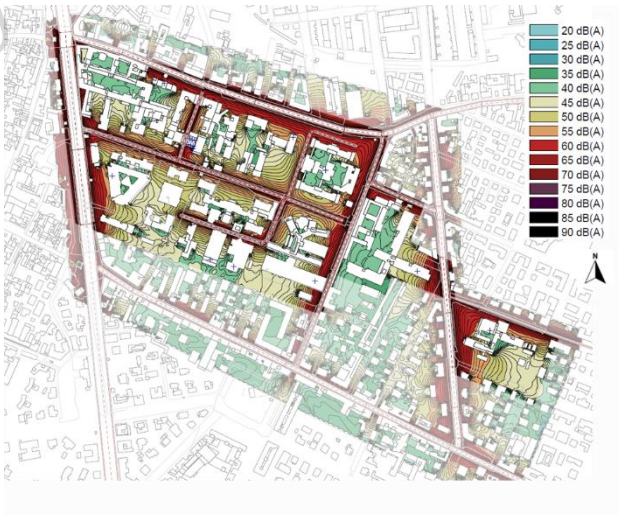

Figure 1. Daytime sound pressure level map of Sant'Orsola University Hospital.

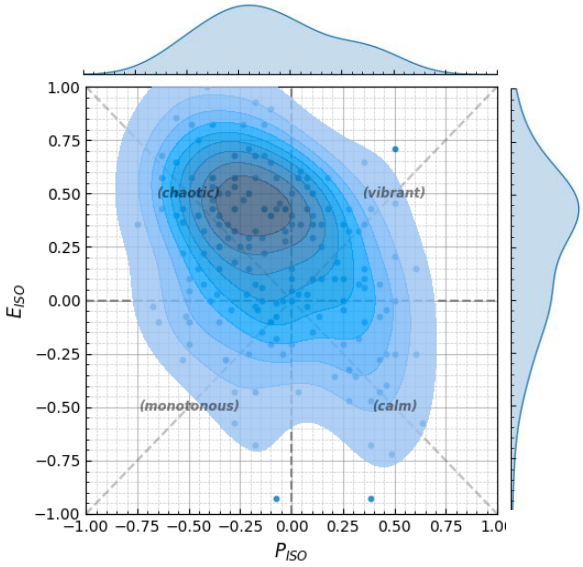

Figure 2. Soundwalk assessments represented in the ISO Pleasantness (P_{ISO}) – ISO Eventfulness (E_{ISO}) circumplex model.

The relationship between modelled exposure and soundwalk responses shows that higher traffic exposure is generally associated with evaluations in the eventful–chaotic–annoying region of the circumplex model (see Figure 2). These perceptual conditions reflect the simultaneous presence of traffic, emergency movements, service operations, construction noise, and dense pedestrian activity. Conversely, protected courtyards and semi-enclosed spaces tend towards calmer, more pleasant conditions, particularly where traffic exposure is reduced, and natural or human sounds become more audible. Similarly, vegetation does not automatically create a restorative soundscape when traffic remains perceptually dominant, since its acoustic benefit also depends on source control, shielding, distance, temporal patterns, and coherence between audible natural elements and the visual setting [11]. The circumplex representation, therefore, provides a structured description of the existing perceptual conditions and establishes a baseline against which alternative scenarios and future changes can be assessed [12,13]. In line with the European Environment Agency, access to quiet areas and natural elements can reduce annoyance and support well-being [14]. These findings support the early integration of acoustic and perceptual criteria into hospital planning through a multidisciplinary, human-centred approach addressing mobility, landscape, accessibility, and healthcare functions.

4. Conclusions

This study shows that the outdoor acoustic environment of Sant'Orsola University Hospital is strongly influenced by internal mobility and other anthropogenic sources. Acoustic monitoring and modelling identify critical conditions along the main internal road, while soundwalks reveal a clear perceptual contrast between traffic-exposed areas and more protected courtyards. The results confirm that sound pressure levels alone are insufficient to describe hospital outdoor environments. Combining physical and perceptual evidence provides a more complete basis for identifying critical areas, defining appropriate soundscape targets, and assessing design alternatives. Hospital regeneration should address internal mobility, protect quiet and restorative spaces, and integrate acoustic objectives with landscape, accessibility, and healthcare functions from the earliest design stages. Future work will extend monitoring campaigns and integrate soundscape results with lightwalks, olfactory assessment, microclimate, air quality, orientation, perceived safety, and accessibility, supporting transferable guidelines for healthier and more restorative outdoor healthcare environments.

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