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The Role of Façades in the Composition of Urban Soundscapes

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Abstract. As cities continue to expand and densify, understanding how buildings affect people's perception and experience of the acoustic environment in context becomes more relevant. This paper presents a conceptual framework of the influence of façades on the urban soundscape, based on the ISO 12913 series, in order to analyze the three main elements of the soundscape: *people, acoustic environment* and *context*, along with *façade* as a fourth element. The methodology included literature review, as well as an exploration of the ISO 12913 methods for soundscape assessment via soundwalks and laboratory experiments involving a total of forty-three (n = 43) participants. The results provide a promising framework for façade analysis to progress toward the integration of human-centered approaches into the field of façade acoustics and complement current building physics practice.

Keywords: Acoustics · Soundscape · Perception · Noise · Comfort · Sustainability

1 Introduction

The growing field of soundscape studies is addressing the gap between noise control and quality of life by considering sound environment as perceived, in context, through an interdisciplinary approach [1–4]. This paper presents the development of a conceptual framework to evaluate the influence of façades on the urban soundscape, based on the definitions of ISO 12913 series for soundscape studies [5–7], as well as considering the progress of the Soundscape Indices SSID project [4, 8, 9].

The framework of façades and urban soundscape was developed through a series of steps involving literature review, soundwalks, field measurements, 360-degree video recordings, binaural and ambisonics recordings, acoustic and psychoacoustic analysis, and laboratory experiments with virtual reality (VR). Since the gap between soundscape research and real-world practice is one the main challenges for the discipline [10, 11],

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the feasibility of using the framework in practice was examined through workshops with Master students of façade engineering. The framework is intended to be a tool to collect the essential information to analyze the relationship of any façade in its unique context and respective soundscape. A brief description of the elements of the framework is presented, followed by a discussion and conclusions.

2 Methodology

2.1 Evidence of Façades Affecting the Acoustic Environment or the Soundscape

A systematic literature review following the procedures of PRISMA [12] was conducted in a previous study by the authors [13]. A total of forty peer-reviewed articles were selected since they reported how the façades of buildings affected the acoustic environment (in terms of building physics), or the soundscape (people's perception). A lack of consistency in the methodologies was observed and explicit applications of ISO 12913 for façade design have not been identified. Additionally, results of a subsequent umbrella review [14] highlight the potential benefits of green walls on health and well-being due to acoustic effects and benefits to the soundscape.

2.2 Soundscape Assessment Following ISO 12913

In September 2022, a series of soundwalks at a university campus in Detmold, Germany, were conducted [15] to explore the ISO 12913 framework's potential for assessing the impact of façades on the urban soundscape. Thirty participants were guided in order to evaluate their perception through a questionnaire while the sound levels were being measured. The study suggested that while ISO 12913 is valuable for soundscape assessment, collecting additional data on façades is still necessary in order to understand their influence on the soundscape.

2.3 Integrating Façade Engineering and the Soundscape Approach

In 2023, two complementary studies were conducted: a laboratory experiment using virtual reality (VR) for audio-visual stimuli with six participants [16], and a soundwalk with seven participants [17]. In both cases, the acoustic environment, context and people's perception were surveyed following the international standard. However, several assessments of a location with different façade states were conducted, allowing the possibility of evaluating how façades can affect soundscape descriptors such as perceived affective quality, and how façades can affect the acoustic environment in terms of decibels and psychoacoustic indicators. The adapted framework turned out to be a useful tool for façade analysis. A follow-up upscaled experiment with more participants was recommended.

2.4 Testing the Applicability of the Conceptual Framework

In order to test if the four-element framework is a feasible approach to evaluate the influence of façades on the soundscape, a workshop was conducted [17] with fourteen participants, all students of the façade engineering Master's program MID at the Detmold School of Design in Germany. The conceptual framework of façades and soundscape was successfully implemented by the student groups to identify potential façade effects. A feedback survey distributed after of the workshop indicated that all participants agreed that the content of the workshop is relevant for façade education, and that the acquired knowledge contributed to improving their façade design skills.

3 Results

Based on the literature review of façade effects [13] and on the pilot studies exploring the methods of ISO 12913 for soundscape research [15–17], a novel framework for analyzing the influence of façades on urban soundscape has been proposed. Figure 1 shows the four main elements (façade, context, acoustic environment, people), along with their respective parameters, interactions and effects. It was derived from the definition of "soundscape" of the ISO 12913 series: "the **acoustic environment** as perceived or experienced and/or understood by a person or **people**, in **context**" [5]. The framework for designing soundscape in urban open public spaces [18] was also considered. The elements of those previous frameworks of soundscape have been integrated along with the **façade** as an independent element isolated from the context to examine how they influence soundscape descriptors (perception).

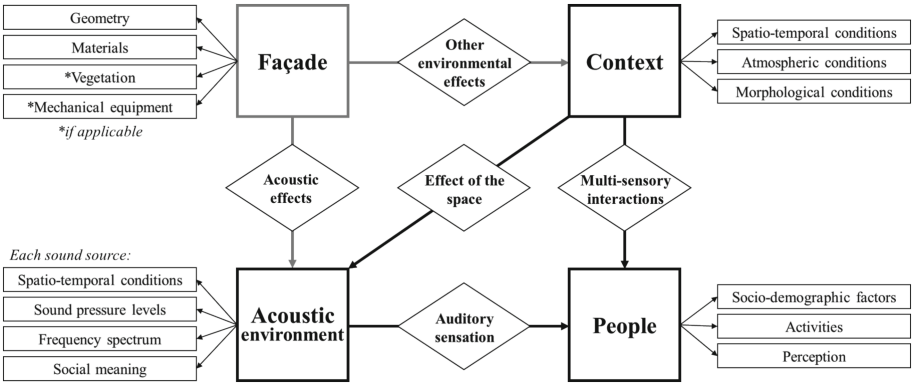

Fig. 1. A conceptual framework of façades and urban soundscape describing the interactions and effects between four elements and their main parameters.

3.1 Façade

This framework considers the "façade" as the vertical surfaces of the building envelope, including the walls, doors, windows, parapets and depending on the case, possibly parts

of the roof [19, 20]. The outdoor side of building envelopes constantly interacts with the urban acoustic environment, and for over two decades, interdisciplinary research has been increasingly conducted to examine those interactions [13]. Depending on the morphological and atmospheric conditions in a given urban context, sounds propagate towards façades and are reflected away, after absorbing and some sound energy and transmitting some of it indoors. Sound-reflective façades can increase sound pressure levels by up to 3–9 dB [21, 22]. At a micro-scale, the intensity of the reflected sound is likely reduced due to absorption and scattering properties of the construction materials. Sound-absorptive façades like those with porous materials or vegetation can lead to reductions of up to 3–6 dB [14, 22, 23], and aside from sound level reduction, green walls can benefit the soundscape due to multi-sensory interactions [14, 17]. Additionally, mechanical equipment on the façade such as air conditioner units or motorized blinds can lead to sound emissions and/or visual effects [16, 17, 24].

3.2 Context

ISO 12913-1:2014 defines the context as "the interrelationships between people's activities in space and time" [5], therefore this framework includes the location and time, urban morphological conditions, as well as atmospheric conditions. Although façades are part of the urban morphology, this framework isolates them from the context to allow the identification of their individual effects.

3.3 Acoustic Environment

ISO 12913-1:2014 defines the acoustic environment as "the sound for a receiver from all sound sources, as modified by the environment" [5]. The background noise, reflection patterns and reverberation are the modifications of the environment/effects of the space [18]. The main parameters related to each sound source include their location over time, sound pressure levels and frequency spectrum, as well as social meaning [18]. The functional relationships between auditory sensation phenomena and acoustic properties can be further analyzed with psychoacoustic indicators [25]. However, they cannot fully describe the soundscape on their own as they are concerned with signal processing and not with people's direct evaluations.

3.4 People

Personal socio-demographic factors such as people's age, gender, country of origin, occupation and level of education are to be considered, as personal factors can lead to different evaluations of sound levels [26]. Additionally, people's activities and behavior in different contexts affect the soundscape [5, 18]. Regarding surveying people's perception, whether it is on-site (e.g. soundwalk) or reproduced (e.g. in virtual reality), a soundscape assessment based on ISO 12913-2:2018 [6] can be used to obtain soundscape descriptors such as perceived affective quality, appropriateness, perceived loudness, and overall soundscape quality among other relevant descriptors.

4 Discussion

Integrating the three elements of soundscape and façades into a single framework proved to be beneficial for investigating potential façade effects on people's perception, a process that currently lacks an established methodology. The framework's adaptability allows analyses at different levels of detail depending on the needs and the available resources. Its application in design and engineering processes offers the promising opportunity to examine the implications of façade design on well-being in terms of physical sound propagation, as well as subjective interpretation.

The framework of façades and urban soundscape is focused on outdoor environments, but it has the potential to be adapted for indoor environments with some modifications such as considering sound transmission effects through the façade, aside from sound reflection, absorption, and emissions.

5 Conclusions

In order to develop a framework to evaluate the influence of façades on the urban soundscape, a series of steps were followed, including a literature review and pilot studies surveying a total combined of forty-three ($n = 43$) people across three soundscape assessment campaigns. Considering that the conceptual framework of ISO 12913 without amendment does not provide sufficient data to understand the effects of façades, this four-part framework is proposed as a novel approach to integrate soundscape criteria into façade design practice. Applying the framework should generally be viable, but the methodology should adapt to the specific needs and resources available. The quality and depth of the results may vary depending on the methodology, so further research to determine systematic applications is intended.

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

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