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The Role of Sound in Shaping Architectural Spaces: A Multisensory Approach

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Abstract: *The integration of sound within the built environment represents a pivotal yet often overlooked aspect of architectural design. This study explores the multifaceted dimensions of sound incorporation, emphasizing its potential to profoundly impact spatial experience and individual well-being. Through a comprehensive review of the literature, the study elucidates the diverse roles sound plays in shaping human perception, social interactions, and environmental quality. Sound, as a fundamental element of sensory experience, significantly influences our perception of space and place. Whether through the subtle ambiance of natural sounds or the deliberate orchestration of architectural acoustics, sound has the power to evoke emotions, establish atmosphere, and define spatial boundaries. Incorporating sound consciously into architectural processes presents opportunities to enhance the quality of life for inhabitants. By prioritizing acoustic comfort and fostering sonic diversity, designers can create environments that promote relaxation, productivity, and social cohesion. Furthermore, leveraging technology and design strategies enables the optimization of soundscapes to mitigate negative sounds and improve overall environmental sustainability.*

Keywords: environmental sustainability

I. INTRODUCTION

The built environment encompasses various architectural spaces, landscapes, and sounds that shape community experiences and interactions.

'Understanding how soundscape influences the built environment is crucial for enhancing the quality of life and well-being of individuals residing in urban areas'(Brown A. L., 2014)

Soundscape, defined as the auditory environment perceived by individuals, significantly impacts the perception of architectural spaces. The integration of soundscape considerations in architectural design and urban planning processes has gained attention in recent years. Features, such as building materials, layout, and spatial configuration, influence the propagation and perception of sound within built environments.

From a psychological perspective, soundscape influences individuals' perceptions, behaviors, and interactions within built environments. Positive soundscapes contribute to a sense of place. Conversely, negative soundscapes can lead to feelings of discomfort, annoyance, and alienation. (Mattia, 2003)

The imperative to explore how soundscape affects the built environment arises from its profound significance for architectural design. In architectural practice, the built environment serves as both a backdrop and a vessel for the sonic experiences that unfold within spaces.

Prevalent Issues

Subjective Perception of Soundscapes

Individuals' subjective perceptions of soundscapes can vary widely. Understanding the factors that influence individuals' preferences and responses to soundscapes is essential for designing environments that cater to diverse user needs and preferences.

Data Collection and Assessment Methods

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The assessment of soundscapes in the built environment involves both objective measurements and subjective evaluations. There is a lack of reliable methods for collecting and analyzing data on soundscapes. It is essential for evidence-based decision-making in architectural design.

AIM

To study the interactions between architecture and sound, and how it affects the thinking and working of people.

OBJECTIVES

- To identify and categorize various soundscapes and examine how these contribute to the built environment.
- To investigate the relation between soundscape and how it affectsan individual's focus and cognitive thinking capacity.
- To explore the use of technology to enhance positive soundscapes and reduce the impact of negative soundscapes.

SCOPE

- The study will cover the psychological effects of sound, and how it can be infused with the overall user experience of built spaces.
- The built spaces include residential, educational, religious, and public leisure spaces (such as museums, community centers, etc.)
- The study will quantify the effects of soundscape.
- The study will present technical details on how soundscape can be introduced or blocked according to the requirements of built environments.

LIMITATIONS

- The study will not cover built environments where only blocking noise plays an important role (such as hospitals, factories, theaters, etc.)
- The study will not cover the physical nature of sound.
- The study will rely on secondhand studies for analysis of how individuals behave to varying soundscapes.
- Music will not be included in the study, being subjective.

II. METHODOLOGY

The research will be divided into three parts, introduction, classification and analysis, and integration.

The introduction will be through already established data on the relation of sounds, built environment, and human perception.

Sounds will be classified according to their effect on human thinking and focus. Data from secondary studies will be analysed and combined to form a quantitative analysis of the effects of these sound types. Relevant primary and secondary case studies will be presented to showcase how the effects of particular soundscapes are utilized.

Finally, a roadmap to soundscape design will be created based on the effect of these soundscapes and strategies to integrate them.

III. PSYCHOLOGICAL EFFECT OF VIBRATION

Vibration, both as a physical phenomenon and a theoretical concept, holds immense importance in human life, resonating across various disciplines from physics to psychology.

String theory, a fundamental framework in theoretical physics, offers profound insights into the nature of vibration at its most fundamental level. According to string theory, the most basic building blocks of the universe are not point-like particles but tiny, vibrating strings.The vibrational patterns of these strings give rise to the fundamental particles and forces that govern the universe, providing a unified description of all known particles and interactions.

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In the context of human life, the importance of vibration becomes evident in myriad ways. From the gentle hum of a lullaby soothing a newborn to the rhythmic beats of music stirring emotions in a crowd, vibrations permeate our existence, shaping our experiences and perceptions. Our brain translates these vibrations to audio, audio we call sounds. "Sound is vibration, transmitted to our senses through the mechanism of the ear, and recognized as sound only at our nerve centers."(Schafer, 1977)

This introductory understanding highlights the significance of sound as a psychological effect of vibration, shaping our understanding of the world and influencing our notions. Through exploring the intricate interplay between vibration, auditory perception, and psychological responses, we can unravel the layered nature of sound and its profound impact on human experience.At its core, sound is not merely the perception of vibrations traveling through a medium but rather a complex psychological phenomenon intricately linked to our senses and cognition.

RANGE OF VISION VS RANGE OF HEARING

In terms of range, human vision typically encompasses a broad spectrum of wavelengths, from approximately 400 to 700 nanometers, corresponding to the colors of the visible light spectrum. This expansive range allows individuals to perceive a wide array of visual stimuli. In contrast, the range of human hearing spans frequencies from about 20 to 20,000 hertz, enabling the detection of sound waves across diverse soundscapes. (Berg, 2020)

However, while both vision and hearing possess considerable ranges, they differ significantly in their spatial and temporal characteristics. Vision offers a high degree of spatial resolution, allowing for detailed discrimination of shapes, textures, and depth. In contrast, hearing excels in temporal resolution, enabling precise detection of rapid changes in sound frequency and intensity.

Vision and hearing are complementary senses that work synergistically to provide a comprehensive understanding of the surrounding world. By integrating visual and auditory information, humans can construct rich perceptual experiences that enhance cognition, emotion, and behavior. (Moore, 2012)

In conclusion, while both vision and hearing are vital senses that contribute significantly to perception, the evidence suggests that humans may perceive certain aspects more effectively through hearing than vision. This assertion is supported by the remarkable temporal resolution of the auditory system, allowing for precise detection of rapid changes in sound frequency and intensity. Moreover, the auditory modality excels in conveying emotional nuances, facilitating social communication and situational awareness (Moore, 2012).

ANALYSIS OF SOUNDSCAPES

The concept of soundscape, introduced by R. Murray Schafer in the late 1960s, revolutionized our understanding of the auditory environment. Soundscape refers to the totality of sounds in a given environment, encompassing both natural and human-made elements(Schafer, 1977). Understanding the soundscape of a place involves analyzing its acoustic characteristics, including the types of sounds present, their sources, their temporal and spatial distribution, and their impact on human experiences and behaviors. By studying soundscape, designers can gain insights into how sound shapes our perception of space, influences interactions, and affects our cognitive senses.

In this context, exploring the concept of soundscape provides valuable insights into the complex relationship between sound, space, and human perception, offering new possibilities for creating more inclusive, enjoyable, and resilient environments for all.

Soundscapes can be broadly categorized into three types: anthrophonic, biophonic, and geophonic. (Zhang Y, Kang J, & J., 2017)Anthrophonic soundscapes encompass sounds generated by human activities, reflecting the impact of human presence on the acoustic environment. Biophonic soundscapes are composed of sounds created by living organisms, excluding humans. These sounds represent the rich tapestry of life in various ecosystems. Geophonic soundscapes include non-biological natural sounds,capturing the Earth's natural acoustic phenomena.(Kang, 2023)

ANTHROPHONIC SOUNDSCAPE

Anthrophonic soundscape, characterized by human-generated sounds such as traffic, construction, and industrial activities, not only affects health and social dynamics but also has a profound impact on cognitive thinking and focus.

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Studies have shown that exposure to high levels of anthropogenic sounds can impair cognitive function and reduce attentional focus (Stansfeld& Matheson, 2003).

Data from six studies is compiled to study how anthrophonic soundscapes affect thinking and focus. In each study, the base score was considered equal to 100 points. After the introduction of the anthrophonic soundscape, equivalent points were calculated. The points after the introduction of soundscape were equal to the percentage increase or decrease in the base score.

Study	Base Score	Base Points	Score after the introduction of Soundscape	Equivalent Points
The effect of noise absorption variation in open-plan offices: A field study with a cross-over design.	8	100	5.3	66
Effects of Soundscape on the environmental restoration in urban natural environments.	7	100	4.2	60
Office noise and employee concentration: Identifying causes of disruption and potential improvements.	5	100	2	44
Environmental stress and health.	83	100	52.2	63
Acoustic comfort evaluation in urban open public spaces.	17	100	8.2	48
The soundscape quality in some urban parks in Milan, Italy.	47	100	25.38	54

Table 1: Data of studies on the effects of Anthrophonic Soundscapes

Average equivalent points = (66 + 60 + 44 + 63 + 48 + 54) /6
= 55.83

The following shows that performance on tasks based on cognitive sense and focus decreased by 45% under the influence of an anthrophonic soundscape. **Therefore, they can be termed as negative soundscapes.**

The effects of anthrophonic soundscape on cognitive thinking and focus include:

- Impaired Concentration
- Reduced Working Memory
- Increased Stress Levels
- Disrupted Learning Environments
- Impaired Problem-Solving Skills

BIOPHONIC SOUNDSCAPE

Biophonic soundscape, characterized by the natural sounds produced by living organisms (except humans) and ecosystems, has been increasingly recognized for its potential to positively impact focus and cognitive thinking. Research suggests that exposure to biophonic sounds, such as bird songs, rustling leaves, and flowing water, can have beneficial effects on mental well-being and cognitive function. (Ratcliffe, Gatersleben, & Sowden, 2013)

Study	Base Score	Base Points	Score after the introduction of Soundscape	Equivalent Points
Effects of Soundscape on the environmental restoration in urban natural environments	46	100	66.7	145
The effects of using a Nature-Sound mobile application on Psychological Well-Being and Cognitive Performance among University students.	48	100	69.6	148
Effects of nature sounds on the attention and physiological and psychological relaxation.	255	100	369.75	145
A synthesis of health benefits of natural sounds and their distribution in national parks	6	100	9	153
The influence of natural sounds on attention	58	100	90	155

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restoration				
Possible mechanisms for the effects of sound vibration on human health	63	100	97	154
Research on the effects of soundscapes on human psychological health in an old community of a cold region	65	100	100	155
Effects of Soundscapes on Human Physiology and Psychology in Qianjiangyuan National Park System pilot area in China	4.9	100	7.5	156

Table 2: Data of studies on the effects of Biophonic Soundscapes

Data from eight studies is compiled to show how Biophonic soundscapes affect focus and thinking capacity. The method used is the same as in Anthrophonic soundscapes.

Average equivalent points = (145 + 148+ 145 + 153 + 155 + 154+155+156) /8
= 151.375

The following shows that performance on tasks based on cognitive sense and focus increased by 51% under the influence of a biophonic soundscape. **Therefore, they can be termed as positive soundscapes.**

The effects of biophonic soundscape on focus and cognitive thinking include:

- Restoration of Attention
- Enhanced Creativity
- Improved Memory Retention
- Stress Reduction
- Enhanced Mood

GEOPHONIC SOUNDSCAPES

Geophonic soundscape, comprised of natural sounds generated by geological and atmospheric phenomena, plays a significant role in influencing focus and cognitive thinking. While geophonic sounds may include the rumble of thunder, the crash of waves, or the rustle of leaves, their effects on cognitive processes have been less studied compared to biophonic or anthrophonic sounds. However, some research suggests that exposure to geophonic sounds can still impact mental states and cognitive function (Payne et al., 2015).

Study	Base Score	Base Points	Score after the introduction of Soundscape	Equivalent Points
The effect of natural ocean sound exposure and Ocean-Side relaxation on chronic tinnitus patients: a pilot study in Korea	5.7	100	7.1	125
When listening to rain sounds boosts arithmetic ability	48	100	60	123
The soundscape quality in some urban parks in Milan, Italy	24	100	29	121
Physiological and psychological effects of forest and urban sounds using High-Resolution sound sources	46	100	55	118
Effects of nature sounds on the attention and physiological and psychological relaxation	5.6	100	7.2	128

Table 3: Data of studies on the effects of Geophonic Soundscapes

Data from five studies is compiled to show how Geophonic soundscapes affect focus and thinking capacity. The method used is the same as in Anthrophonic soundscapes.

Average equivalent points = (125 + 123+ 121+ 118 + 128) /5
= 122.46

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The following shows that performance on tasks based on cognitive sense and focus increased by 22% under the influence of a geophonic soundscape. **Therefore, they can be termed as positive soundscapes.**

Here are some effects of geophonic soundscape on focus and cognitive thinking:

- Restoration of Attention
- Stress Reduction
- Meditative Environment
- Improved Cognitive senses
- Enhanced Creativity

Geophonic soundscapes have a similar effect as biophonic soundscapes, but in a more controlled way.

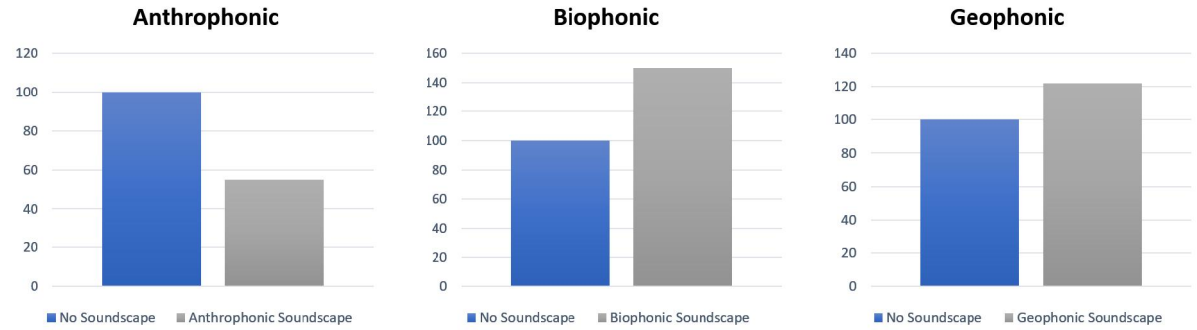

Figure 1 Comparative effect of Soundscapes of focus and cognitive sense

IV. CASE STUDIES

Primary Case Study: Dandi Kutir Museum, Gandhinagar

The Dandi Kutir Museum, dedicated to Mahatma Gandhi, utilizes sound to create an immersive and evocative experience for visitors. Through the strategic use of sounds, the museum brings to life moments from Gandhi Ji's journey and the Indian independence movement. These sonic elements are meticulously synchronized with visual displays and interactive exhibits, enhancing the storytelling and creating a strong emotional impact. The soundscapes not only serve to educate but also to transport visitors back in time, making the historical narrative more vivid and engaging. This multisensory approach ensures that Gandhi Ji's legacy and the spirit of India resonate powerfully with all who visit.

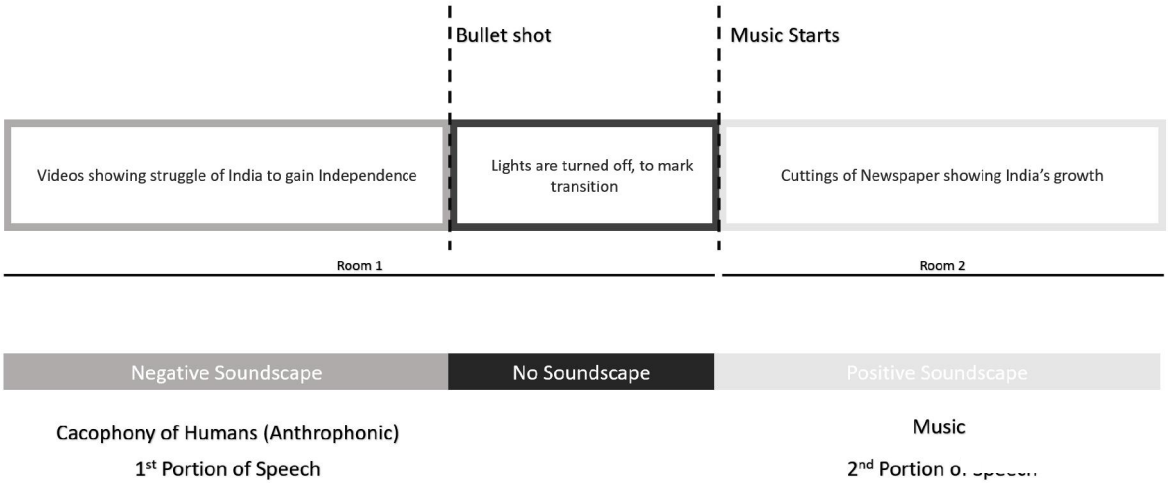

Figure 2 Sequence of sounds, as played at the end of Dandi Kutir Museum

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The above sequence acts as a climax to the museum. With screens on both sides, as one enters the lobby, one can see videos from moments after the partition and a cacophony of people, playing across the displays. The famous speech of Nehru ji starts; at the moment when he says, “When the world sleeps”, a piercing sound of a bullet appears. All the displays get turned off. The bullet sound signifies the one that hit Gandhi Ji.

A door is opened at one end, a bright light comes through; as you enter the next room, music is played, one dear to Gandhi Ji. The second portion of the speech continues and the displays on the wall show stories of the growth of India.

All these emotions are conveyedusing sound, carefully placing it in the built environment. A simple lobby is used to tell a story. The first room depicts sound that forms a negative soundscape (Anthrophonic) and as one moves one enters a positive soundscape. This creates a feeling of happiness. This is an example of how sound can be used to create emotions, here creating adrenaline rush, creating joy.

Primary Case Study: Smritivan Earthquake Museum, Bhuj

To help visitors fully understand the scope and severity of the 2001 Gujarat earthquake, the Smritivan Earthquake Museum uses sound to tell a compelling and immersive story of the event. The museum recreates the sounds of the earthquake, from the first tremors to the thunderous collapse of buildings, using sounds to give visitors a visceral sense of the event's severity. In addition to the sonic experience, speakers positioned at key points play survivor accounts and personal stories, giving the disaster a more human face. By integrating the soundscapes with visual and tactile elements, the museum not only educates but also evokes empathy and a deeper understanding of the earthquake's devastating impact on lives and communities

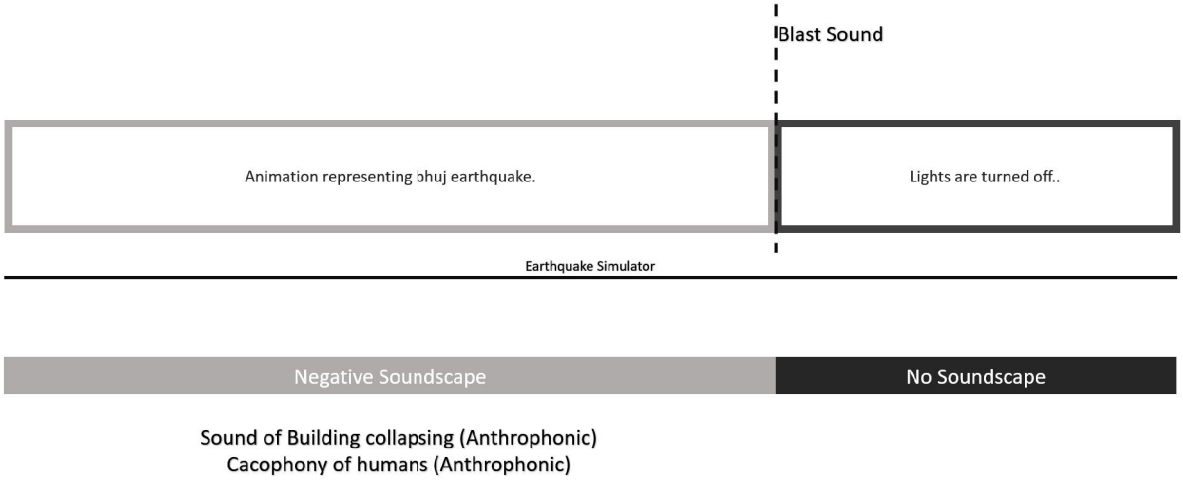

Figure 3 Sequence of sounds, as played at the end of Smritivan Earthquake Museum

The following sequence was played at the end of the Museum. An earthquake simulator was used, placed inside a circular room with a 360^0 display. An animated video is played, showing moments after the 2001 earthquake.

A cacophony of human sounds, superimposed with sounds of structure falling formed an anthrophonic soundscape, which has a negative nature. This was to make their viewers feel the pain of the people caught in this calamity of nature. The built environment, mixed with visuals and sound was used to depict the disaster.

Then the sound of a blast is played, and all lights are turned off. The presenters wanted to leave people with an afterthought of how victims would have felt, trapped in the sequence of earthquake. In this case, no positive soundscape was introduced unlike the prior one, to ignite that feeling of loss, to make people ponder.

This case study stands in striking contrast to the previous one as the sounds are used for exactly opposite feelings. In the previous one, sound was used to give hope to the people, and in this, sound is used to make people feel the agony of the ones who experienced this calamity. This is how actively sound can be used to produce multiple feelings and wove it with the built environment to enhance the overall user experience of the building.

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Primary Case Study: Entrepreneur Development Institute, Ahmedabad

The Entrepreneurship Development Institute of India (EDI) in Ahmedabad incorporates open corridors between classrooms, introducing a biophonic soundscape that enhances the learning environment. These open corridors, designed to blend seamlessly with the institute's lush, green surroundings, allow natural sounds such as birdsong, rustling leaves, and the occasional breeze to permeate. This biophonic soundscape fosters a connection between students and nature, promoting psychological well-being and reducing stress. The design choice reflects an understanding of the positive impacts of natural auditory experiences on cognitive thinking and focus.

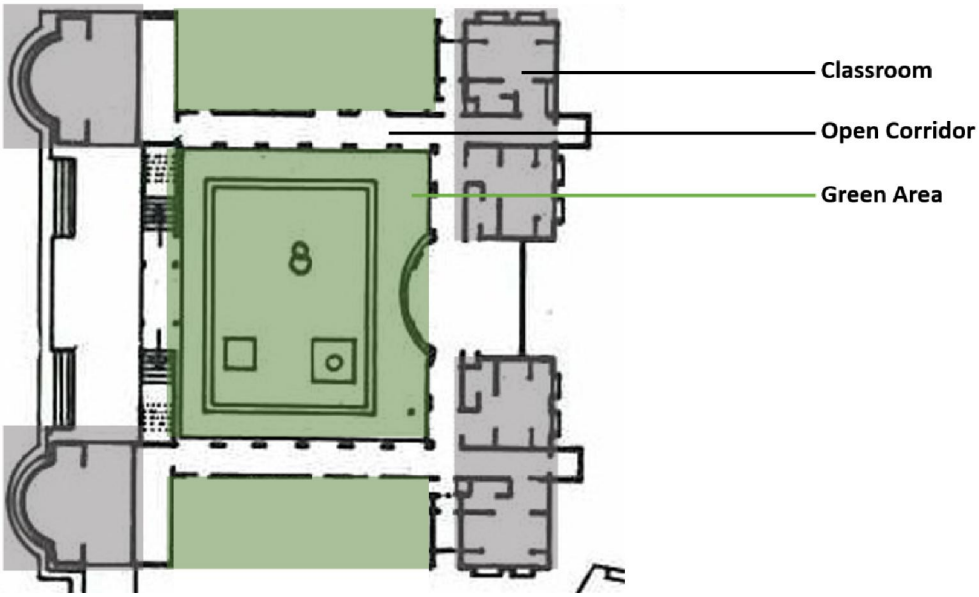

Figure 41 Plan of EDI, Ahmedabad; showing open corridors surrounded by green spaces

This is an example of a passive design strategy, on how soundscape can be introduced to enhance work efficiency. In this example, a biophonic soundscape is introduced which helps rejuvenate students. The biophonic soundscape imparts a positive effect, in contrast to the general anthrophonic soundscape in the classroom.

Flora, which is local to the site, is introduced in the planning, which attracts birds from the surrounding, the sound of birds leads to the creation of a biophonic soundscape. This is beneficial for students as it helps them with better focus and thinking ability.

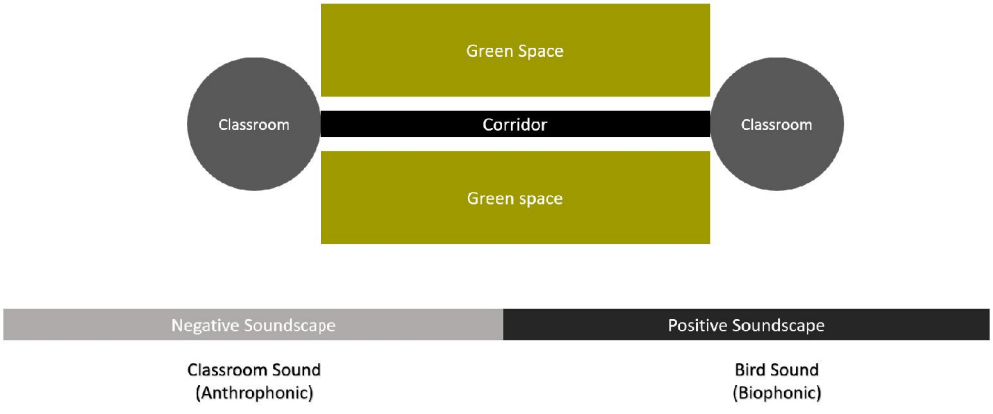

Figure 5 Sequence of Soundscapes in EDI, Ahmedabad

The above figure shows how two contrasting soundscapes are used, to make the user feel the difference between soundscapes, and feel the impact of a positive soundscape, over a negative soundscape.

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Conclusion

While biophonic and geophonic sounds contribute positively, their strategic use alongside anthrophonic sounds can create a dynamic interplay that enriches the sonic experiences and amplifies the intended message of a space. In conclusion, the thoughtful integration of biophonic, geophonic, and anthrophonic soundscapes can create environments that are not only aesthetically pleasing but also emotionally resonant and cognitively simulating.

V. INTEGRATION OF SOUNDSCAPE WITH BUILT ENVIRONMENT

The concept of soundscape refers to the sonic environment as perceived by people, in context, and includes all sounds present, from natural sounds to human-made noises (Schafer, 1994). Integrating sound into the built environment involves the strategic use of auditory elements to enhance the functionality and overall experience of architectural spaces.By considering sound as a vital component in the design process, architects and planners can create environments that are not only visually appealing but also harmonious, contributing to a more holistic sensory experience for the inhabitants.(Axelsson, Nilsson, & Berglund, 2010)

ROADMAP TO SOUNDSCAPE DESIGN

The roadmap to soundscape design involves several steps, criteria, and techniques aimed at enhancing the acoustic environment. The process is divided into two main phases: establishing the acoustic character of the place,and designing and optimizing.

Establish the Acoustic Character of the Place

Define purpose and activities to Determine the primary uses of the space and the types of activities that will occur (e.g., residential, commercial, recreational) (Zhang Y, Kang J, & J., 2017)

Consider project objectives and involve stakeholders: Engage with all relevant parties to ensure their needs and expectations are met (Jeon, Hong, & Lee, 2013).

Identify listening places and itineraries: Determine key locations where sound will be experienced.

Identify sound sources and components.

Perform soundwalks: Conduct experiential walks to understand the current soundscape (Schafer, 1994).

Measure and characterize sound components.

Design and Optimize

Soundscape design is a multidisciplinary field that focuses on the creation, management, and optimization of sonic environments.This can be achieved by addressing three basic parameters: the introduction of wanted sounds, the retention of wanted sounds, and the removal of unwanted sounds. (Jeon, Lee, You, & Kang, 2010)

Introduction of Wanted Sounds

The introduction of wanted sounds involves the deliberate incorporation of sounds that contribute positively to the soundscape. These sounds are typically chosen based on their ability to enhance the environment and improve the auditory experience for individuals.

This introduction can be approached through two fundamental methods: active and passive measures.

Active measures involve the deliberate introduction and manipulation of sounds using technological tools and strategies. Active measures are particularly effective in environments where targeted sound interventions are needed to improve the auditory experience, such as in museums, parks, and urban spaces.

On the other hand, passive measures focus on the natural and structural aspects of managing sound. Passive measures aim to minimize unwanted noise and enhance desirable sounds through design.

Active Measures

Speakers and Sound Systems:

Fixed Speaker Systems: Strategically placed speakers can be used to introduce ambient sounds.

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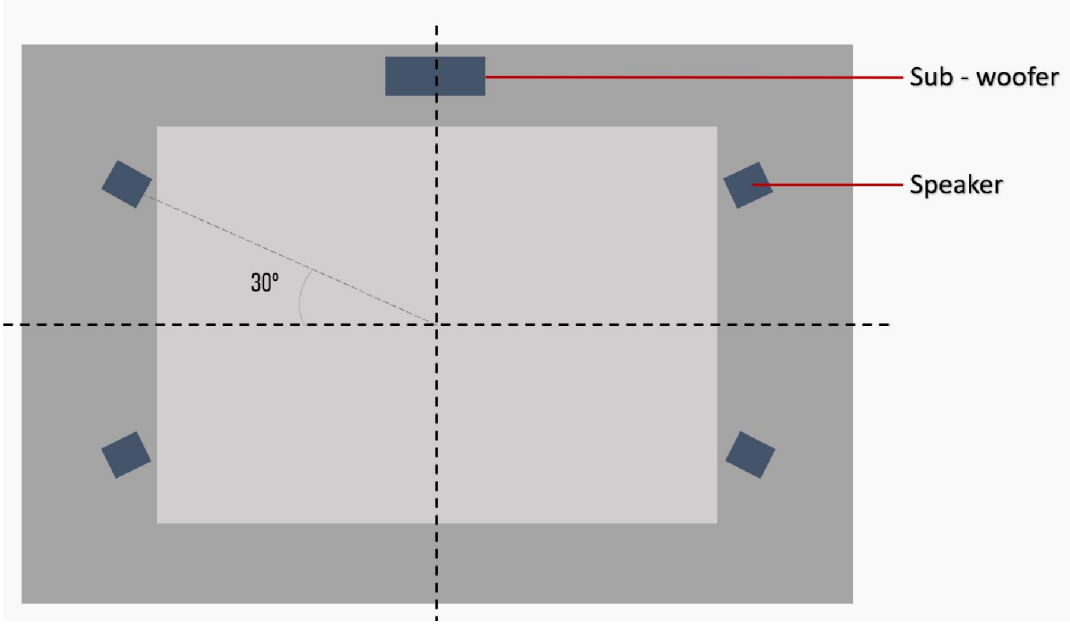

Figure 2 Speaker Placement

Positioning speakers at a 30-degree angle from the center can significantly enhance ambient sound. This arrangement creates a wider soundstage, allowing audio to envelop the listener from various angles rather

than just straight ahead. By dispersing sound in this manner, speakers can simulate a more natural listening environment.

Headphones:

Focused Sound Delivery: Headphones create a highly personalized sound experience. For example, at the Dandi Kutir Museum, headphones allow visitors to hear detailed historical accounts and ambient sounds that bring the exhibits to life. This ensures that each visitor can engage deeply with the content on display, such as listening to speeches, music, or environmental sounds relevant to the exhibit, without interfering with others.

Figure 3 Headphones as used in Dandi Kutir Museum, Gandhinagar

Passive Measures

Biophonic environments can be created by:-

- Planting native flora can attract birds and insects, adding natural sounds to the environment.

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- Setting up bird baths and feeders can attract birds, enhancing the biophonic experience.
- Installing vertical gardens or green walls can provide habitat for small wildlife, enhancing the biophonic environment.
- Designing green roofs with vegetation can attract birds and insects, creating a biophonic environment.
- Using hedges, shrubs, and other plantings to create natural sound barriers that also serve as habitats for wildlife.
- Using building materials and designs that provide habitats for wildlife, such as birdhouses integrated into walls or eaves.
- Designing surfaces that reflect and amplify natural biophonic sounds, such as water features with stone surroundings that enhance the sound of bird calls.

For Geophonic Soundscapes: -

- Installing fountains, waterfalls, or water walls can provide the calming sounds of flowing or splashing water.
- Gravel or pebbled paths can produce natural crunching sounds, adding to the geophonic ambiance.
- Wooden surfaces, such as decks, can produce creaking sounds, contributing to the natural soundscape.
- Earth mounds, boulders, or rock formations can enhance natural sound reflections and absorptions.
- Placing wind chimes in areas with natural airflow can add soothing, melodic sounds to the environment.
- Using hedges, shrubs, and other plantings to create natural sound barriers that also serve as habitats for wildlife.
- Aeolian Harps, played by the wind, produce harmonic sounds when the wind passes through them.
- Integrating small artificial streams or ponds with gentle flowing water can create a tranquil soundscape.

Architectural Integration

Permeable surfaces are critical in design for managing sound permeability.

Types of Permeable Surfaces

Perforated Panels

- Materials: Metal, wood, plastic, and composite materials.
- Design: Panels with a series of small holes or slots.

Brick Jali

- Materials: Brick, and terracotta.
- Design: Traditional lattice designs that create intricate patterns.

Perforated Metal Screens

- Materials: Steel, aluminum, and stainless steel.
- Design: Metal sheets with various patterns of perforations.

Design Considerations

Material Selection

Choose materials that balance durability, maintenance, and aesthetic appeal. For example, perforated metal screens are durable and low-maintenance, while brick jali offers a traditional look with good ventilation properties.

Pattern and Perforation Size

The size and pattern of perforations or openings should be designed to achieve the desired balance between sound permeability, light transmission, and privacy.

Integration with Building Systems

Ensure that permeable surfaces are integrated with other building systems such as HVAC, lighting, and structural elements to optimize their performance and functionality.

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Consider the local climate and environmental conditions. For example, green walls and roofs are highly effective in areas with high temperatures, while perforated panels may be more suitable in regions requiring enhanced ventilation and shading.

Maintenance

Plan for the maintenance of permeable surfaces, especially green walls and roofs, which require regular care to sustain plant health and structural integrity.

Retention of Wanted Sounds

Retention of wanted sounds is about preserving and enhancing the beneficial sounds already present in the environment. This parameter ensures that desirable sonic elements remain prominent despite potential changes in the surrounding area.

This can be done through Reflection, Reverberation, and Resonance.

Reflection

- Stone and Concrete: These materials are dense and reflective, making them effective at bouncing sound waves. Stone walls, pathways, or water features can amplify sounds like footsteps, water splashes, or bird calls.
- Water Features: The design of water features can significantly impact sound. Cascading waterfalls, rippling streams, or fountains with strategically placed elements can amplify the sound of water.
- Sound Walls: Constructing walls or barriers that reflect sound towards certain areas can help amplify natural sounds. These can be made from stone, concrete, or other reflective materials.
- Sound Mirrors: These are large, concave structures that reflect and focus sound waves. Originally used for military purposes, they can be adapted for landscape design to amplify natural sounds.

Reverberation

Shape and Layout:

- Curved Surfaces: Incorporate curved walls, ceilings, or domes, which help distribute sound evenly and enhance reverberation.
- High Ceilings: High ceilings allow sound to travel further before being absorbed, increasing reverberation time.
- Large Open Spaces: Large, open areas with minimal obstructions to facilitate sound reflection.

Surface Materials:

- Hard, Reflective Surfaces: Use materials like stone, glass, concrete, and metal for walls, floors, and ceilings. These materials reflect sound waves effectively, prolonging reverberation.

Architectural Features:

- Sound Reflectors: Use strategically placed sound reflectors to direct and spread sound within the environment.

Strategic Placement:

- Sound Sources: Position sound sources (like speakers or musical instruments) in areas where the sound can reflect off multiple surfaces.

A prominent example of reverberation can be seen in St. John's Baptistery

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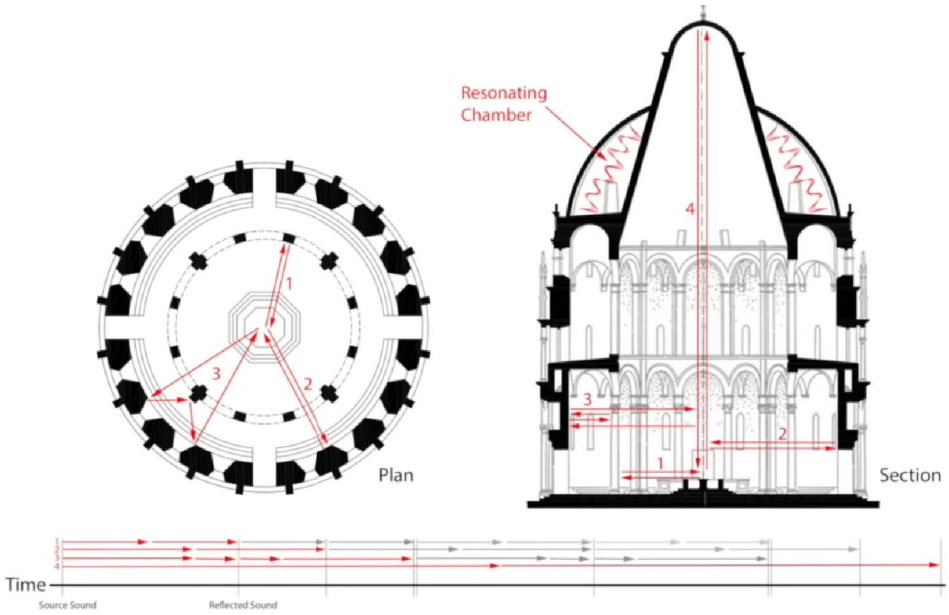

Figure 4 Reverberation in St. John's Baptistery

The Baptistery of St. John in Pisa, Italy, is a renowned example of designing sounds. The baptistery creates 4 different reverbs, that highlight the prayers. The first reverb is due to the inner colonnade; the second one is due to the outer colonnade; the third reverb happens when the reflected sound, from the outer colonnade, gets trapped between the inner and outer colonnade and gets reflected a second time; and the fourth reverb is due to the high ceiling. The ceiling is installed with a resonating chamber, which highlights the fourth reverb.

Resonance

Room Shape and Dimensions:

- Rectangular Rooms: Simple rectangular rooms with dimensions that relate to the wavelengths of desired sound frequencies can enhance resonance.
- Cylindrical and Spherical Shapes: These shapes naturally enhance resonance due to their uniform distance from the center, which can reflect sound waves to the source.

Size and Volume:

- Larger Spaces: Larger volumes can sustain sound longer and enhance low-frequency resonance, creating a fuller sound.

Wall and Ceiling Materials:

- Hard Surfaces: Use materials like plaster, concrete, brick, and wood for walls and ceilings. These materials reflect sound waves, contributing to resonance.
- Panel Resonators: Install panel resonators, which are panels mounted over an air cavity. They can be tuned to resonate at specific frequencies, enhancing certain sounds.

Acoustic Features:

- Helmholtz Resonators: Integrate Helmholtz resonators, which are cavities designed to resonate at specific frequencies. These can be built into walls or ceilings.

A prominent example of resonance can be seen in the Hypogeum of HalSaflieni in Malta

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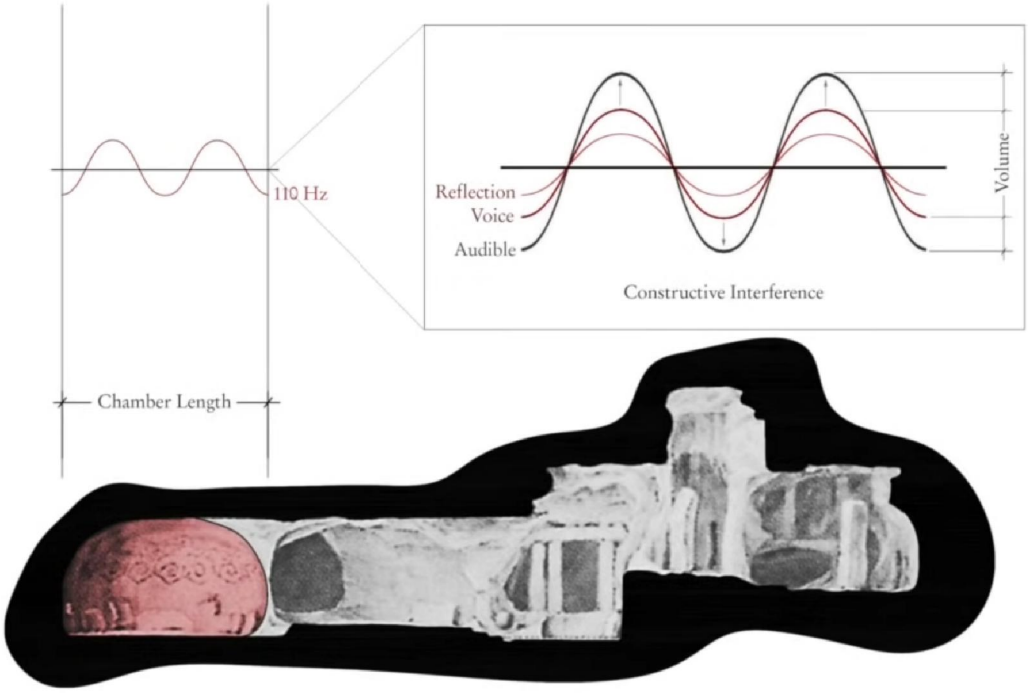

Figure 5 Hypogeum, Malta

The hypogeum was built around 3000 B.C.E. It consists of an oracle chamber that was specifically designed to resonate with the frequency of 110Hz. The frequency is equal to the frequency of the sound of prayers offered by male priests. The chamber length was created in multiple of the wavelength, corresponding to the frequency of 110 Hz. This leads to the creation of a standing wave. The amplitude of this standing waves increases due to constructive interference from multiple reflected waves. This enhances the sound of prayer, giving it a transcendental feel.

Removal of Unwanted Sounds

The removal of unwanted sounds, or noise, is essential for creating a pleasant and functional soundscape.

Architectural and Structural Solutions

Mass and Density:

- Double Walls
- Insulated Walls

Diffusive Surfaces:

- Bookshelves and Furniture
- Textured Wall Coverings

Sound Barriers and Absorption:

- Plants and Green Walls
- Perimeter Green Belt
- Hedges and Shrubs
- Earth Mounds and Rocks
- Other natural barriers

Acoustic Treatments

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Acoustic Panels:

- Foam Panels
- Fabric-Wrapped Panels

Carpets and Rugs:

- Thick Carpeting

Curtains and Drapes:

- Heavy Curtains

Behavioural and Operational Strategies

- Sound Management Policies
- Scheduling.

VI. CONCLUSION

In this research, we delved deeply into the profound impact of sound on architectural spaces and the human experience. Through a comprehensive examination of soundscapes, which encompass biophonic, geophonic, and anthrophonic elements, we have underscored the significant yet often overlooked role that sound plays in architectural and urban design.

Our study began by exploring the psychological effects of various sound. Natural sounds, such as those from biological sources (biophonic) and environmental phenomena (geophonic), were found to have a generally positive impact on mental health, stress recovery, and cognitive performance. These sounds contribute to creating environments that are soothing and restorative, fostering a sense of calm and relaxation. Conversely, human-made noises (anthrophonic), typically associated with urban environments, can often lead to stress and discomfort. However, we also discovered that, when used strategically, these sounds can enhance educational and therapeutic outcomes by creating dynamic and engaging auditory experiences.

Our research underscores the importance of considering sound as a fundamental component of sustainable and human-cantered design. Prioritizing sonic comfort and fostering diversity allows designers to create spaces that support relaxation, productivity, and social cohesion. Such environments improve the quality of life for inhabitants and reflect a deeper understanding of the interplay between humans and their surroundings.

In conclusion, the insights gained from this dissertation highlight the transformative potential of integrating soundscapes into architecturaldesign. By embracing the auditory dimension as an essential aspect of design, we can create environments that are more attuned to the needs and well-being of their inhabitants, paving the way for healthier, more sustainable, and more enjoyable spaces.

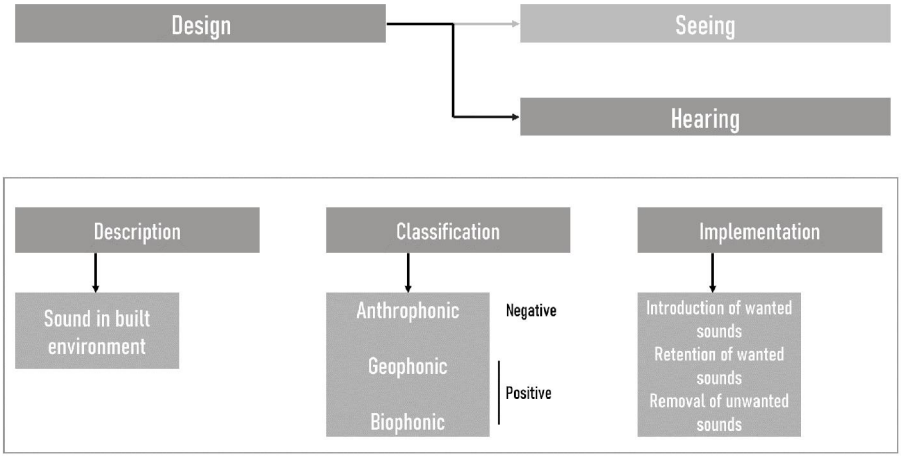

Table 4 Soundscape Design

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