A MULTIDISCIPLINARY SOUND DESIGN FRAMEWORK FOR ARCHITECTURAL DESIGN

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ABSTRACT

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One of the main goals of architecture is to achieve a multi-sensory experience for users. The multi-sensory experience aims for the coherence of perceptual data entry in the context of the function of the spaces. When the user experiences a space designed by an architect, one is under the influence of a diverse and intense flow of perceptual data. Auditory perception of the environment is affected by both physical and sociocultural factors. Today, the auditory analysis of spaces is mostly studied under the multidisciplinary subjects of architectural acoustics, soundscape, multisensory interactions, and sense of place. However, the sound design discipline used in movie and video game literature since the beginning of the 20th century has yet to be noticed in architectural literature. The concept of sound design has been integrated in product design since the early 90s, but it has not found its desired place in the architectural and architectural acoustic literature. The main aim of the thesis is to present a new proposal to the sound source classification methods in the literature within the framework of sound design analysis and synthesis methods, which have an essential place in the film and game sectors of the sound elements in the built environment. This proposal will help architects and designers to classify sound elements in the built environment according to the functions of spaces.

Keywords: Architecture, Multi-sensory experience, Sound design, Built environment

ÖZET

MİMARİ TASARIM İCİN DİSİPLİNER BİR SES TASARIM MODELİ

ÖZDEMİR, Doğukan
İç Mimarlık Yüksek Lisans

Tez Danışmanı: Dr. Öğr. Üyesi Kıvanç KİTAPCI
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Mimarlığın temel hedeflerinden biri, kullanıcıların çok duyulu deneyimini kurgulamaktır. Çok duyulu deneyim, söz konusu mekânın işlevi bağlamında algısal veri girişinin tutarlılığını hedeflemektedir. Bir kullanıcı, mimarın tasarladığı bir mekânı deneyimlediğinde, algısal verilerin yoğun ve çeşitli akışı altında kalır. Günümüzde mekanların işitsel analizi, mimari akustik, işitsel peyzaj, çok duyulu etkileşim ve yer duyusu ana başlıkları altında, çoğunlukla disiplinler arası çalışılmaktadır. Ancak, literatürde görmezden gelinen ana konu, bu değerlerin tamamını hali hazırda gözeten, film ve video oyunu sektörlerinde 20. yüzyılın başından beri kullanılan ses tasarımı disiplinidir. Ses tasarımı kavramı, 90'lı yılların başından beri endüstri ürünleri tasarımında geniş yer bulmuş, ancak mimarlık ve mimari akustik literatüründe gereken yeri bulamamıştır. Ses tasarımı, güncel mimarlık literatüründe büyük yere sahip olan mimari akustik, işitsel peyzaj, çok duyulu tasarım ve yer duygusu konuları arasında kuvvetli bir köprü niteliği taşımaktadır. Bu tezin temel amacı, film ve video oyun sektörlerinde önemli bir yere sahip olan ses tasarımı analiz ve sentez yöntemleri çerçevesinde literatürdeki ses kaynağı sınıflandırma yöntemlerine yeni bir öneri sunmaktır. Bu öneri, mimarların ve tasarımcıların yapılı çevredeki ses öğelerini mekanların işlevlerine göre sınıflandırmasına yardımcı olacaktır.

Anahtar Kelimeler: Mimarlık, Çok duyulu deneyim, Ses tasarımı, Yapılı çevre

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LIST OF SYMBOLS AND ABBREVIATIONS

ISO	:International Organization for Standardization
SPL	:Sound Pressure Level
RT	:Reverberation Time
Pa	:Pascals
Eq	:Equation
dB	:Decibel
IEC	:International Electro Technical Commission

CHAPTER I

INTRODUCTION

In the modern world, sounds are all around us. Numerous sound sources can be found in our physical and natural environments, and each transmits unique audial messages to our cognitive system. The principal aim of architectural design is to augment the multisensory perception of space users (Pallasmaa 2005: 41). The multisensory experience aims at the consistency of perceptual data in the context of the preferred function of the space (Spence 2020: 14). The design of the holistic and multisensory experience is commonly disregarded in contemporary western society, where visual concerns take center stage. Because the built environment should consider both the auditory experience and the sensory and affective consequences of sound, it should not be separated from the design process. Architectural acoustics and soundscape are two disciplines that study the auditory designs of spaces. These fields do not delineate their boundaries, and research in the literature typically favors multidisciplinary approaches. This thesis aims to present a new proposal to the sound source classification methods and model in the literature within the framework of sound design analysis and synthesis methods, which have an essential place in the film and video game sectors of the sound elements in the built environment. For this purpose, the existing sound design models in the literature were examined and adapted to the auditory environment in architecture. An extensive library of sound sources has been created, and the sound samples added to the library have been classified within the framework of three different sound classification systems (five layers of sound design, diegetic/non-diegetic sounds, and consequential-intentional sounds). Finally, the sound design model was developed using the sound samples in the created sound library.

1.1 JUSTIFICATION OF THE RESEARCH

Every visual and auditory component of the built environment perceived by the public should be approached with the foresight and expertise of a designer. These sound sources, or what we refer to as audible design elements, need to be thoughtfully made, controlled, or placed. However, sound sources must first be classified as a design element in the design process. This thesis aims to present a new proposal to the sound source classification methods in the literature within the framework of sound design analysis and synthesis methods, which have an important place in the film and video game sectors of the sound elements in the built environment. It has been noticed that the discipline of sound design, which is at the center of the cinema and industrial design disciplines, is ignored in the built environment literature.

In sound design, designers frequently place generated or recorded sound layers coherently with the visual layer and the scenario's environment, such as conversation, music, and effects. Therefore, each sound design is unique to the user, subject, narrative flow, and time. Today's sound designers typically complete the design process intuitively. The consistency and calibre of the visual and aural information improve the audience's overall understanding of the narrative structure. Visual or auditory aspects in movies are not chosen at random. If the audience hears a sound, it has been intentionally created, recorded, or synthesize. Information, meaning, and emotion are all conveyed in sound design. Similarly, every auditory and visual component of the built environment should be created with the designer's knowledge and foresight in mind. Sound design is based on making sounds aesthetic, understandable, and suitable for the human ear (Dakic 2007: 2).

When the literature is considered, it becomes evident that three layers must be examined for identifying sound sources as design elements: (1) soundscape, (2) diegesis, and (3) intention. Every feature is considered a different classification layer. The first of these classification layers is the sound source types being widely researched in soundscape research. The audio elements of the built environment are generally classified within the soundscape subject and as suggested in the relevant standard (ISO 2018). The standard's presented classification model only functions as a guideline and bases its decisions on reliable sources. Although many methods can be used to classify sound sources, the most widely used methods in the soundscape literature are the semantic differential method, which is used with factor analysis to reveal basic orientations, and cluster analysis (Bones et al. 2018: 4).

Most of these classification methods are based on the work of Schafer (1977), which is the basis of the soundscape. It was discussed that other studies in the literature examined environmental sounds under various classification methods. Bones et al. (2018) investigated sound sources' classification in the soundscape literature. In addition, the sound classification of indoor auditory environments has also been examined in the literature (Ercakmak and Dokmeci Yorukoglu 2020). Finally, the ISO (2018) has published a method proposal for classifying the acoustic environment for the soundscape.

The second layer, which we refer to as diegesis, aims to create spatial consistency across sociocultural, contextual, and geographic boundaries. This layer applies to film and video game theory to the diegetic/non-diegetic classification method. The third and final layer is where the sound designer defines the limits of this control over the sound sources. It is used in various disciplines, including sound design, film production, television production, video game development, and musical instrument development. When the literature is examined within the scope of these studies, it is seen that sound design in industrial products has increased rapidly. These studies focus on various subjects, especially acoustic measurements and product sound quality, and have a multidisciplinary structure (Kusitzky 2018). In another study, Spence and Zampini (2006) also investigated the sounds of everyday objects from a multi-sensory perspective. As a result of this study, it has been suggested that the sounds of everyday objects affect the users' perception of quality and efficiency. In product sound design, the sounds generated by the product are classified as intentional and consequential sounds (Ozcan and Van Egmond 2008: 306/2).

A literature matrix is prepared chronologically and listed based on the literature review (Table 1) to identify the gap regarding sound design and sound source categorization. Studies on the fundamentals of sound, architectural acoustics, and sound design in movies and video games are frequently found in the literature on sound design and sound categorization. When the different research areas are compared, it becomes clear that there are enough studies on product sound design, soundscape sound categorization, and product sound categorization in the literature. Still, there are, unfortunately, not enough studies on sound design in acoustic literature.

Table 1: A literature matrix of studies in the literature regarding sound, soundscape, and sound design approach.

Researches in Literature	Acoustic and Sound	Architectural Acoustics	Films and Video	Sound Design	Soundscape	Product Sound Design	Sonic Interaction Design	Product Design Categorization	Films and Video Games Categorization	Soundscape Categorization	Arch. Acoustics Categorization	Audio Technology
Hansen, C. H, 2001	x											
Schmidt-Jones, C, 2004	x											
Brouwers, M. A. J. 2008	x	x										
Schulze, H. 2019	x			x								
Laleli, Sonat 2019	x											
Abokhalil, A. 2020	x											
Egan, David, 2007	x	x										
Bruel & Kjaer 1978	x	x										
Dudley, L. M. 1998				x								
Cipriani, A., & Giri, M. 2010				x								
Dal Palù, D., De Giorgi, 2018				x								
Shilling, R., & Krebs, E. 2002			x	x								
Vesna Dakic, 2007			x	x					x			
Grimshaw, M. 2010			x	x								
Ozcan, E., & van Egmond, R. 2006			x	x		x		x				
Langeveld, L., Van Egmond 2013				x		x						
Benli, K. 2015				x		x		x				
Bazilinskyy, P., Cieler, S. 2018				x		x						
Erkut, C.				x		x		x				
Rocchesso, D, 2008							x					
Hermann, T, 2011							x					
Malchaire, J. 2001												x

Table 1 Continued

IASA-TC 2004												x
ISO, 2004												x
Owsinski, B. 2005												x
Huber, D. M., & Runstein, R. 2012												x
Chattah, J 2014												x
Marrington, M. 2017												x
Clauhs, M. 2020												x
Shilling, R., & Krebs, E. 2002									x			
Whittington, W. 2007									x			
McGregor, I., Leplâtre, G					x					x		
Brown, A. L., Kang, J., 2011					x					x		
Salamon, J., Jacoby, C. 2014					x					x		
Dokmeci Yorukoglu, P. N., 2017					x					x		
Trudeau, C., & Guastavino, C. 2018					x					x		
Oliver,Bones, Trevor J. Cox. 2018					x					x		
Lafay, G., Rossignol, M. 2019					x					x		
Torresin, R., Aletta, F., Babich, T., 2020					x					x		
Squadrone, G., & Bacchi											x	
Mastino, C. C., Concu, G. 2019											x	
Squadrone, G., & Bacchi								x				
Langeveld, L., van Egmond. 2013								x				
Bazilinskyy, P., Cieler, S. 2018								x				

The proposed sound design model for the thesis and two sound source classification layers are intended to be added to the sound source classification methods currently used in the soundscape literature. These two additional layers are (1) Diegesis, which measures the contextual, sociocultural, and geographical coherence of the sound source with the built environment, and (2) Intention, which measures a sound designer's degree of control over the design element. Experimental studies were carried out in three different spaces with varying functions within the scope of the thesis. These three venues were a restaurant, an open office, and an urban area. Detailed information about the selected venues is explained in Chapter 4.

1.2 AIMS AND OBJECTIVES

The thesis aims to present a proposal for the sound source classification methods in the literature within the framework of sound design analysis and synthesis methods, which have an essential place in the film and video game sectors of the sound elements in the built environment. This proposal will help architects and designers to classify sound elements in the built environment according to the functions of spaces. For this aim, the research questions and hypotheses within the scope of the thesis are as follows:

1. RQ_1: Can the sound source classification method, widely used in the film and industrial product design fields, be integrated with the soundscape classification method in the literature to be interpreted as designer-oriented?
2. RQ_2: Can designers use an integrated sound source classification method-based interdisciplinary sound design framework model as a design guide?

1. H_1: The sound design method used in the film and video games industries can be a guideline for architects and other environmental designers. With the developed sound design model (CLIC), the sound source classification method used in film and industrial product design can be integrated and used in the sound environment classification method in the literature.
2. H_2: With the developed sound design model (CLIC), the sound source classification method used in film and industrial product design can be integrated and used in the sound environment classification method in the literature.

In line with the research questions and hypotheses, the aimed objectives are as follows:

1. Collecting environmental sound recordings from the designated venues to review the existing sound design models in the literature.

2. Creating a large environmental sound library.
3. To classify the environmental sound recordings added to the library within the sound design model of sound classification systems as diegetic/non-diegetic and consequential/intentional sounds.

1.3 METHODS

The study was planned to be conducted in two phases to accomplish the main objectives of this thesis:

1. Phase 1: Environmental sound recordings were taken from three venues and categorized. Online web-based listening tests were conducted.
2. Phase 2: Sound design processes were carried out for three different venues.

1.3.1 Recording Sound Sources and Web-Based Listening Test

The thesis was planned for sound recordings in three venues: restaurants, open-plan offices, and urban spaces. For restaurants, environmental sound recordings were collected from two different restaurants (Big Chefs and Coffee Craft Town), an open office (Ace Mimarlık), and an urban space (Tunalı Hilmi Street) in the Çankaya district of Ankara. These three locations were picked for the recordings because of their high levels of foot traffic, regular daily use, and wide variety and variability of sound sources. Shotgun-type and X/Y-type microphones were used to record the environmental sounds, and the recording angles were set to 120 degrees. 140 cm above the ground is where the microphones are fixed. Ableton Live 11 Suite Digital Audio Workstation (DAW) software was used to post-production the sound recordings that were gathered. Each collected sound recording is fifteen minutes long, and the isolated headphone connected to the Focusrite 2i2 audio interface was used for the sound source identification procedure. Each sound source identified was listed in detail.

The analyzed environmental sound recordings were taken from the Affective Digitized Sounds-Extended (IADS-E) (Yang et al. 2018) database for listening tests. Each received sound source was six seconds long and digitally normalized. The primary aim of the web-based listening tests is to determine the diegesis value of each identified and listed sound source. Listening tests were made using the Web Audio Evaluation Tool, commonly applied in studies on sound source identification in the literature (Jillings et al. 2015). A total of 32 people actively participated in the web listening tests. The detailed information on the listening tests is explained in detail in Chapter 4.2.2.

1.3.2 Sound Design Process

In the second phase of the experiment, the soundscape designs of the three different venues (restaurant, open-plan office, and urban space) were carried out. With the aid of the soundscape design system set up in the building physics lab of the Çankaya University Faculty of Architecture building, the participants brought their designs to life. Ableton Live software was used with Digital Audio Workstation (DAW) during the soundscape design. The sound output of the software running on the computer was processed on the Focusrite Scarlett 2i2 external audio interface and transmitted to the designer via Beyerdynamic DT770 Pro closed headphones with high sound quality. Control of the software is provided by Korg NanoControl 2 external midi control interface.

1.4 OUTLINE OF THE THESIS

Chapter 2 initially explains the literature on architectural acoustics with physical characteristics of sound, building acoustics, and room acoustics. Then this chapter explains the soundscape in the literature. This section examines urban soundscape and indoor soundscape studies in the literature. After the title of soundscape, sound design and its three sub-titles are explained. (Fundamentals of sound design, sound design in film theory, product sound design). Finally, taxonomy is mentioned in Soundscape, film theories, and product sound design.

Chapter 3 explains the proposed environmental sound design model. The sound design model presented in this thesis is based on the methods called Diegesis and Intention, derived from film, video games, and product-based sound design theories.

Chapter 4 explains what methods are applied in this thesis. Firstly, sound recordings collected from three different venues are explained. Then, listening tests were carried out with the participants. Then, the participants participated in the sound design experiment for the three selected venues.

Chapter 5 explains the results of the first phase of the thesis, collecting environmental sound recordings and web-based listening tests in detail. Also, chapter 5 explains the sound design process, results, and statistical data, which is the second phase of this thesis.

CHAPTER II

LITERATURE REVIEW

In this chapter, the sound design discipline, which is ignored in the literature and is at the center of the film and video game industries, is explained and discussed. The chapter first describes the physical characteristics of sound. In addition, architectural acoustics with two sub-topics, room, and building acoustics, are examined in detail in this section. Secondly, soundscape, the first of the two essential features considered while classifying sound sources in the literature as design elements, is examined and explained under the indoor and urban soundscape titles. Then, the sound design discipline, is examined and explained. In the continuation of the sound design discipline, sound design in industrial products, whose studies in the literature have been increasing rapidly, has been examined and explained. Later, sound classification methods in the literature on soundscape, film theory, and product design are examined and described in detail. Finally, the literature's current studies of sound design and sound source taxonomy disciplines are examined and explained in detail under the title of key studies.

2.1 PHYSICAL CHARACTERISTICS OF SOUND

The perception of sound is what the human ear experiences in response to sudden changes in air pressure. These alterations are typically brought on by a vibrating object that induces airborne longitudinal wave motion (Ginn 1978: 9). For Ginn (1978), sound waves belong to a specific category of waves called elastic waves, which are a broader classification of waves. Sound is called vibration in an elastic medium such as air, water, most building materials, and the earth. Sound energy moves quickly, causing minimal changes in atmospheric pressure, and it can travel long distances. On the other hand, each vibrating particle moves only an infinitesimal amount to either side of its normal position (Egan 2007: 2). The physical properties of sound can be divided into three, frequencies, wavelength and amplitude.

Frequency is measured in hertz (Hz). Describing the rate of oscillatory and vibratory phenomena, such as mechanical vibrations, sounds, radio waves, and light frequency, is a crucial parameter in the science and engineering (Ginn 1978: 11). In physics, the wavelength is the length over which a periodic wave repeats or its spatial period. The wave's crest is its highest point, while its trough is its lowest (Ginn 1978: 13). In science, amplitude refers to the most significant displacement or distance a point on a vibrating body or wave moves relative to its equilibrium position. Sources that vibrate produce waves, with the amplitude of the waves being proportional to the source's amplitude (Ginn 1978: 13).

Today, auditory designs of spaces are studied under the titles of architectural acoustics and soundscape. These disciplines need to have sharp boundaries and studies in the literature generally prefer interdisciplinary approaches. The following section explains architectural acoustics and soundscape disciplines with sub-titles.

2.2 ARCHITECTURAL ACOUSTICS

Architectural acoustics is the scholarly examination of sound creation, dissemination, and transmission within rooms and other buildings (Ginn 1978: 8). Acoustics, as it relates to architecture, utilizes building design and construction techniques to maximize sound effects. Architectural acoustics refers to sound production, transmission, and propagation in zones and other structures (Ginn 1978: 8). Architectural acoustics plans a building's interior to maximize, amplify, and lower noise levels as sound waves reflect off it where it makes sense. Since we are all aware of the sounds we are exposed to every day, whether consciously or unconsciously, indoor spaces' acoustics significantly impact the quality of our daily life. The user's quality of life can be improved by correctly applying the architectural acoustics discipline (Schroeder 1980). Architectural acoustics consists of two main topics: room acoustics and building acoustics. Room acoustics aims to ensure that all listeners receive the sounds from the sound source in the volume in the best possible way. The goal of building acoustics is to determine how sounds from inside or outside the building insert various building component.

2.2.1 Room Acoustics

Room acoustics is the science of measuring the movement of sound waves in confined spaces by studying their interaction with surfaces for various reasons, including sound preservation. According to Ginn (1978: 34), sound waves will travel away from the source until they come into contact with one of the room's boundaries. Some sound energy will be reflected into the room, while others will be absorbed and transmitted through the boundary. The room acoustics are defined by the complex sound field produced by the multitude of reflections and the behavior of this sound field as the sound energy in the room is allowed to build up and decay (Ginn 1978: 36). The three elements of room acoustics are sound absorption, sound pressure level, and reverberation time.

Sound Pressure and Sound Power Level

When a microphone is placed in a sound field, the amount being measured is the sound pressure level (Ginn 1978: 37). According to IEC (2009), sound pressure level (SPL) is a logarithmic measure of the adequate sound pressure of a sound relative to a reference value. It is expressed as a percentage of a standard reference level in decibels (dB). The typical reference for sound pressure in air or other gases is 20 Pa, commonly regarded as the human hearing threshold (IEC 2009).

$$\mathrm{SPL} = 20\ \log_{10}\left(\frac{\mathrm{p_{rms}}}{\mathrm{p_0}}\right)$$

Eq1

where SPL is expressed in decibels and P_0 is the reference sound pressure level of 0,00002 P_a. The reverberation time varies according to the volume and absorbency of the space. Considering the Sabine formula, the reverberation time will increase as the space volume increases. Accordingly, increasing the total absorbency of the space will decrease the reverberation time (IEC 2009).

Similar relationships exist between a sound source's sound power output and the sound pressure levels in a space. The sound pressure level in the space will increase due to the source's sound energy. The sound pressure levels will vary depending on our proximity to the source and the room's properties, but the source's sound power level is independent of the room (Ginn 1978: 18).

The Sound Power Level measures the acoustic energy emitted from a noise source, expressed in decibels. As defined by IEC, the ratio of a given sound power to the reference sound power is the sound power level. This power level is ten times the ratio's logarithm to base ten in the decibels (IEC 2009).

$$\text{Sound Power Level} = 10 \log_{10}\left(\frac{W}{W_0}\right)$$

Eq2

where W is the source's acoustic power and W 0 is a reference acoustic power of 10–12 W, the sound power level is expressed in decibels (Ginn, 1978).

Sound power or sound intensity measurements can be used to calculate sound power. The direct and comparison methods are two ways to calculate sound power from sound pressure measurements. The direct method can be applied in a reverberant sound field, but it is most frequently used in environments that are essentially free field. However, the comparison approach is restricted to reverberant sound fields. In the direct method, sound pressure measurements are taken at various locations on an imagined surface that encloses the tested device. These sound pressure level measurements are adjusted for the impact of the acoustical environment by spatially averaging them (Ginn 1978: 19).

Reverberation Time

Reverberation time is one of the most crucial aspects of a room's acoustics. It is important in determining a room's suitability for a given use (Ginn 1978: 37). W.C. Sabine conducted extensive research on room acoustics at the beginning of the twentieth century. Sabine discovered an empirical relationship between the volume of the room, the amount of absorptive material present, and a quantity known as the reverberation time. This consistency, which Sabine called the residual sound of audibility duration, is now used as the reverberation time (Egan 2007: 62). The reverberation time of a casing is defined as the duration required to reduce the sound pressure level of a continuous noise by 60 dB after the source is switched off. In most cases, the difference in sound pressure levels between background noise and the primary sound source is less than 60 dB (Ginn 1978: 37). This relationship is now known as the Sabine formula:

$$T = \frac{0.161V}{A}$$

Eq3

Reverberation time (T) is the volume of the room (V) and the total area of absorption in room (A). Sabine's formula is usually deduced theoretically using geometrical acoustics and the assumptions that the sound in the enclosure is diffuse and that all directions of propagation are equally probable (Ginn 1978: 38). Reverberation time varies according to the volume and absorbency of the space. Considering the Sabine formula, the reverberation time increases as the space volume increases. However, increasing the total absorbency of the space will decrease the reverberation time.

Eyring's formula is an additional computational method that is obtainable. The difference between the two equations is that Eyring's formula is based on intermittent decay, whereas Sabine's formula assumes a diffuse field.

2.2.2 Building Acoustics

Building acoustics is the science of controlled noise in buildings. This includes minimizing noise transmission from one space to the following and controlling sound characteristics within those spaces. Building acoustics are an important consideration in the design, operation, and construction of most buildings, and they can significantly impact people's health, productivity, and communication (Ginn 1978: 68). Sound can spread through the building through the air or the structure of the building. Ginn (1978) classified sound generation mechanisms into two broad categories. The first category includes sources that emit sound directly into the air, such as voice, loudspeakers, etc. Airborne sound insulation is used to protect against such noise. The second type of source acts directly on the structure of the building, usually by using impact or vibrating equipment (Ginn 1978: 62). Figure 1 shows the noise as a combination of airborne and impact noise because impacts generate airborne noise, which is transmitted. In almost all cases, however, the noise produced in the receiving room by transmitting the impact noise will take precedence.

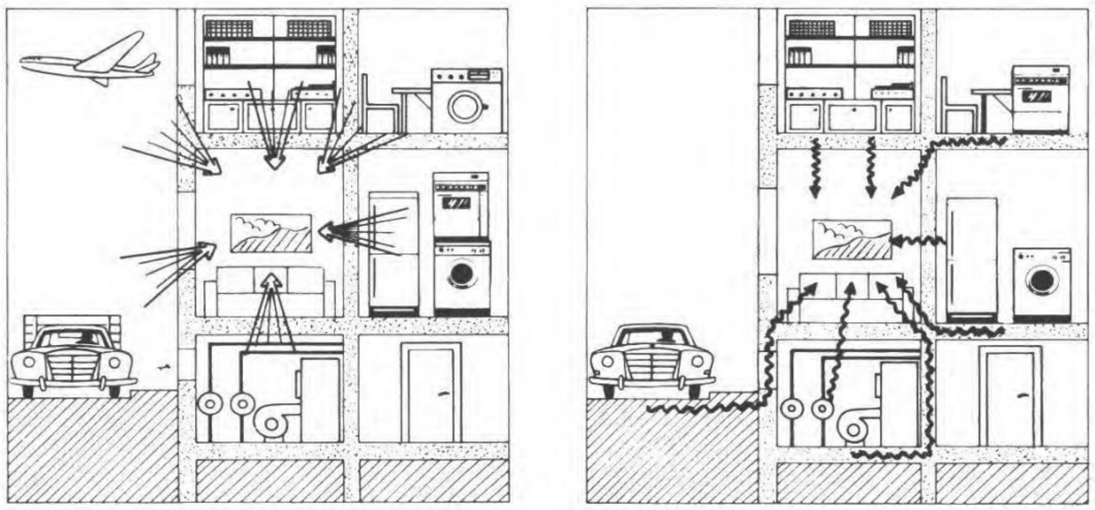

Figure 1: Intrusive noise due airborne noise (left), structure borne noise (right) (Ginn 1978: 61)

2.3 SOUNDSCAPES

The term soundscape was proposed by R. M. Schafer in the 1960s, in line with his pioneering research on the subject, to define the acoustic environment resulting from multiple sound sources and environmental interaction. Schafer first defined the term "soundscape" in his book Our Sonic Environment and The Soundscape - The Tuning of the World (Schafer 1977) . The soundscape theory, which was created by Schafer (1977), is a framework for integrating perceptual components and the acoustics of a space. Soundscape is a term that describes a group of sounds in a place and how those sounds are perceived. Therefore, the physical and perceptual characteristics of the aural environment are considered and covered by current soundscape research. Schafer (1977), asserts that soundscape research aims to make a bridge between science, society, and the arts. This term is about the physical characteristics of sound and how the human brain interprets sound from acoustic and psychoacoustic. Society should also consider how people react to sounds and how different sound sources affect people's behavior. The soundscape approach is multi-disciplinary and can encompass areas as varied as engineering and environmental psychology. The soundscape was developed based on different ideas focusing on studying the human perception of acoustic environments and architectural features. Furthermore, soundscape studies aim to prefer ambient sounds as a source instead of waste and bring a new perspective to the noise control research field Dokmeci Yorukoglu and Kang 2016). Sound sources are crucial components of the environment's characteristics in soundscape studies. Through that perspective, factors that contribute to the overall sound environment and the subjective responses to the actual sound environment are investigated to produce pleasing and favored soundscapes. Sound sources are crucial components of the environment's characteristics in soundscape studies. From this standpoint, various elements contributing to the comprehensive soundscape and subjective reactions to the acoustic surroundings are analyzed to produce an agreeable and desirable soundscape (Dokmeci Yorukoglu and Kang 2016).

This next section will explain and discuss the two primary topics of soundscape theory: urban and indoor soundscape.

2.3.1 Urban Soundscapes

Numerous sound sources can be found in urban soundscapes, each with unique physical and semantic characteristics. The sound sources in an urban soundscape are determined by the geographical and socio-cultural context of a particular environment (Schafer 1977: 43). The relationship between personal experience and subjectivity in a physical and sociocultural context is thus considered by the soundscape. According to Schafer (1977: 43), urban soundscapes were complex acoustic environments that provided clues about socio-cultural life over time. Schafer explained the development of urban soundscape in two terms, hi-fi and lo-fi. A system that has a good signal-to-noise ratio is considered hi-fi. Because there was less background noise, specific sounds may be heard clearly in a hi-fi environment. Less sound overlap occurs in a hi-fi soundscape, and the foreground and background are perceived differently.

On the other hand, perspective is lost in the lo-fi soundscape since individual acoustic signals are masked by the thick sound ensemble (Schafer 1977: 71). Urban sounds were thus both a significant design component and an inherent aspect of urban life. The coherence of the sound and visual design elements present in the urban environment has been well-documented in the literature to impact the residents' well-being directly. Therefore, the environmental designer's goal should be to create a built environment that is holistic and tailored specifically to the sociocultural and geographic context in which it is located (Kitapci and Ozdemir 2021b :2). Using well-known design criteria, including the physical characteristics of a place, acoustic factors, and user characteristics, it would be helpful for urban planners and architects to build a method to anticipate the subjective evaluation of soundscape quality by possible users (Kang 2008). A soundscape can be viewed from a global to a local perspective and is always variable in time and space. The perceived scale of a sound source is finite if the sonic environment of a given area can be transformed into an acoustic representation of a city (Raimbault & Dubois, 2005).

According to Raimbault and Dubois (2005), the obvious salient factor describing the environment of cities, 'traffic' is interpreted as causing noise annoyance if ideal urban soundscapes should reflect life through sounds communicating human presence and activities. These findings indicate that in order to create new urban soundscapes, urban planners should take these psycho-social experiences as well as physical requirements into consideration. Raimbault and Dubois (2005) argued that in addition to noise level measurements, semantic features attributed to sound sources must also be looked at to assess the urban soundscape. With these ideas taken from communication science and semiotics, a model is thus proposed that supports the classification of auditory events (Figure 2). As shown in Figure 2, analysis of the verbal data also showed that urban planning requires mediation between various interests with a shared objective. The place and function of noise in cities were constrained in light of the primary requirements for an urban project.

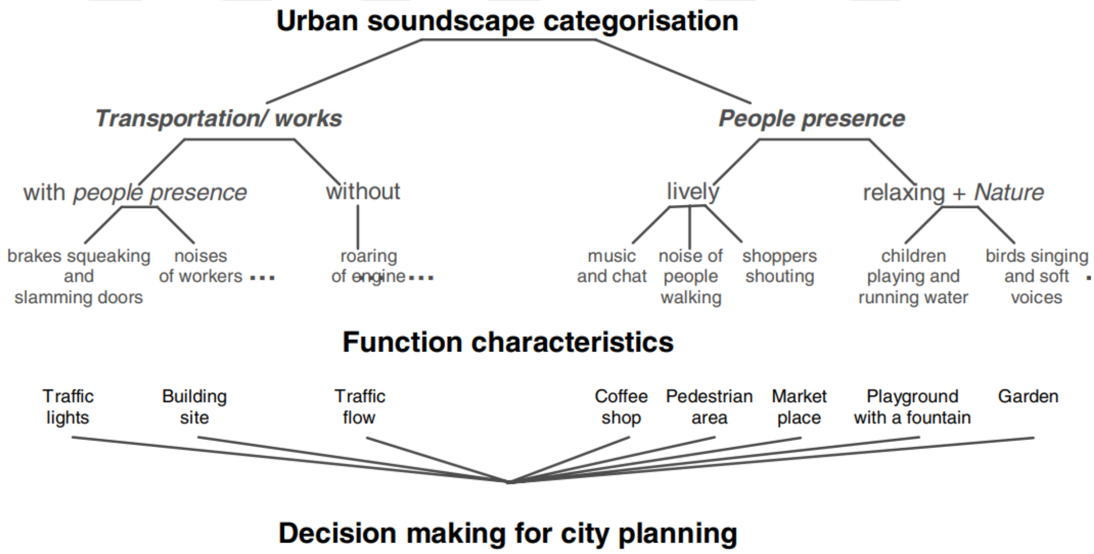

Figure 2: Comparison between planners and city-users' verbal descriptions of urban soundscapes. (Raimbault and Dubois 2005:346)

Ozcevik and Yuksel Can (2012: 131) summarize the results of the complex interaction between sound source, the physical environment, and humans in Figure 3 after a comprehensive search of the soundscape literature. The main model of soundscape studies is summarized in Figure 3, which was created after a thorough review of the soundscape literature. However, a review of the relevant literature reveals that there is no consensus regarding subjective and objective data characteristics, the procedures for gathering and analyzing the data, or the statistical techniques to be applied in the correlation.

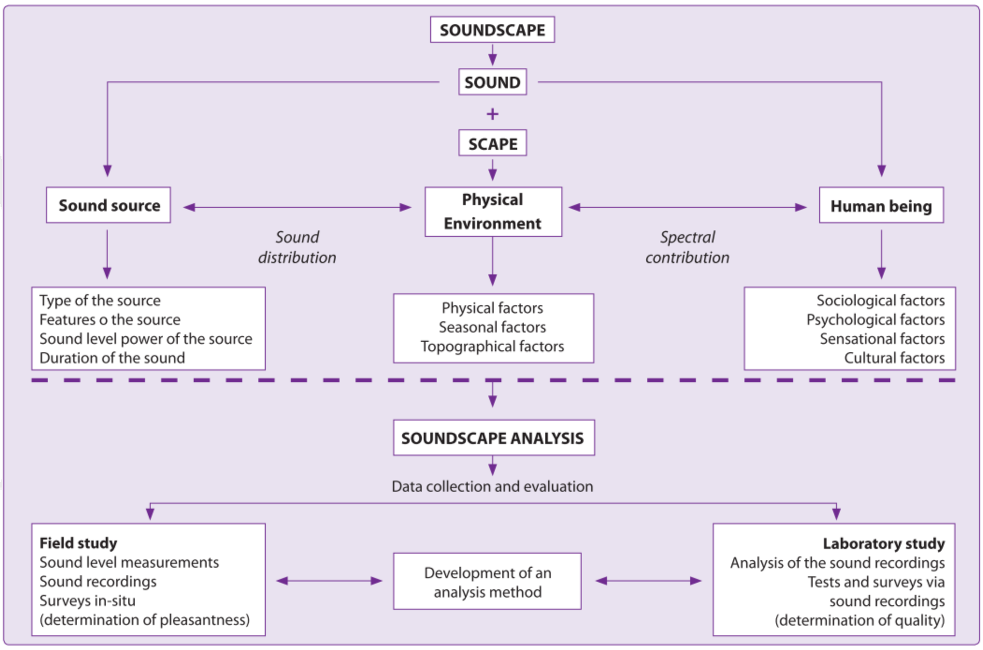

Figure 3: The complex interaction among sound source, physical environment and human being, at the soundscape research. (Ozcevik and Yuksel Can 2012: 131)

As a result, categorical space planning in cities about the idea of urban soundscape is mentioned in studies on sound evaluation in daily life. Regarding urban projects, urban planners should consider the idea of the urban soundscape. In this situation, acoustic specialists, urban users, and planners should permit comparisons between categories and work toward a reduction in noise levels (Raimbault and Dubois 2005: 346).

2.3.2 Indoor Soundscapes

The development of indoor soundscapes has progressed through various methodologies, primarily focusing on examining acoustic environments, architectural features, and human perception (Dokmeci Yorukoglu and Kang 2016). An individual sense that benefits from experiencing a given space determine how that individual perceives that space. Five senses (vision, hearing, smell, tactility, and taste senses) that regulate how one perceives space are used to gather information about it (Aburawis and Dokmeci Yorukoglu 2018: 5).

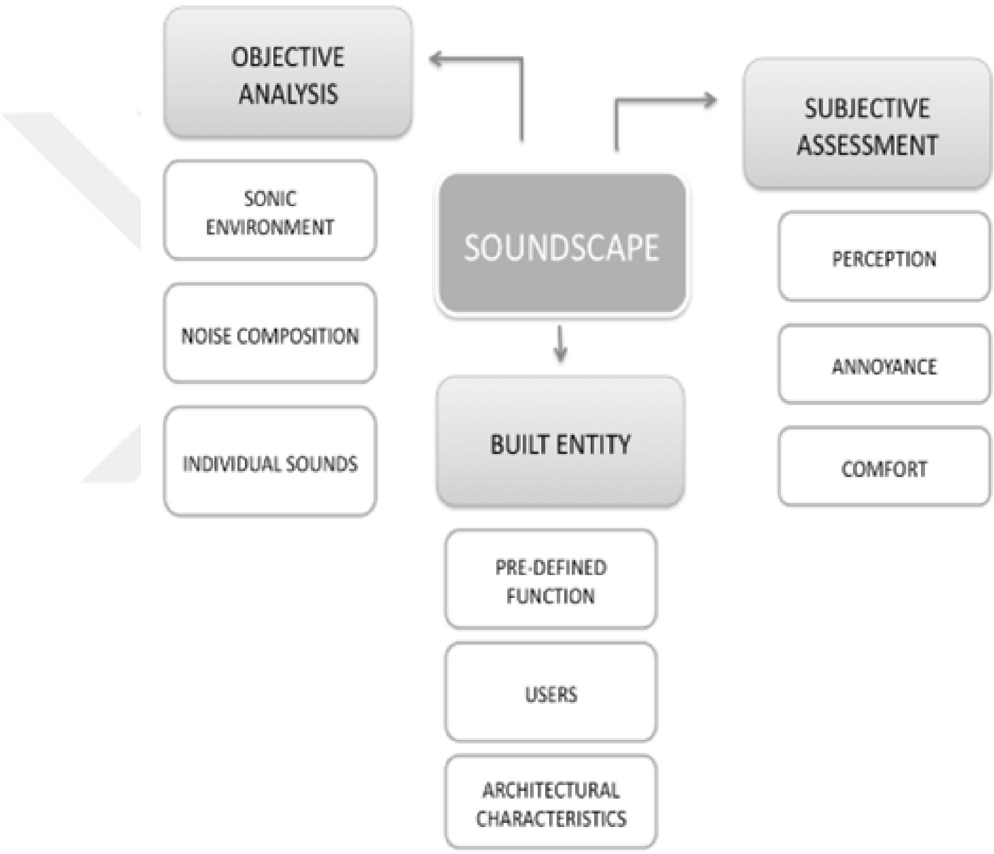

Figure 4: Three main aspects of soundscape research.(Dokmeci and Kang 2010: 1)

Incorporating the built entity variable, which specifies the evaluation of architectural characteristics, is the first and most crucial factor that separates indoor soundscaping from urban soundscaping. According to Dokmeci and Kang (2016), concerning indoor soundscapes, the use and purpose of a space, its physical attributes, and spatial characteristics are just as significant as the objective and subjective assessments of the sound and environment. In an enclosure closely related to building acoustics and related research fields, spatial characteristics play a crucial role in the sound and its formation. Accordingly, it is essential for an indoor soundscape study to analyze the characteristics and architectural whole of an indoor space.

Framework (Figure 4) developed by Dokmeci and Kang (2010: 1) aims to understand the three aspects of indoor soundscapes. According to the framework, the three main components of sound environment assessment are the evaluation of the built entity, the subjective evaluation, and the objective analysis. To comprehend users' sensory experiences in a particular sound environment, or the soundscape, combining these three factors points us toward a psychological perspective instead of a physical noise control technique (Dokmeci and Kang 2010).

Urban soundscape and room acoustics were the two primary acoustic concepts that constitute this essential component of indoor soundscaping. Thus, the indoor soundscape methodology acknowledges various methods by combined approaches from the two research areas to develop its study framework. (Dokmeci Yorukoglu and Kang 2016: 204).

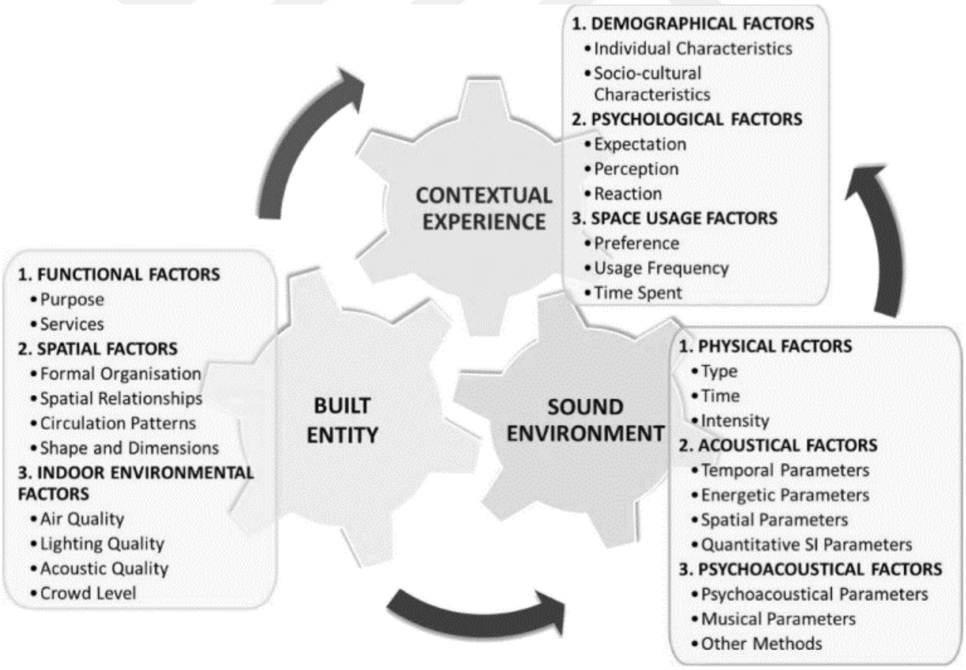

Figure 5: Collaborative system wheel of indoor soundscaping framework with the three main variables and nine related factors. (Dokmeci Yorukoglu and Kang 2016: 204)

Dokmeci and Kang (2016) developed a framework for indoor soundscape factors (Figure 5). This framework comprises three main groups: sound environment, contextual experience, and built entity. Under the heading "sound environment" in that framework, acoustical characteristics and psychoacoustical factors are highlighted. User data is divided into contextual experience factors, which capture user perception, and built entity factors, which include functional, spatial, and environmental considerations.

2.4 FUNDAMENTALS OF SOUND DESIGN

This section explains the discipline of sound design that has been overlooked in the literature and is at the center of the film and video game industry. Then, the discipline of sound design in film theory and industrial product design, which we encounter with many studies today, is explained.

Most of us frequently encounter sounds throughout our daily lives. Sound sources the presence of other people, animals, objects, and even environmental events like a thunderstorm (Cuadrado et al. 2020). Sound conveys information, attracts users' attention, or affects their attention; it is frequently used in media applications or products. Film, TV series, documentaries, and video games all use sound and music to enhance the viewing experience for their audiences by enhancing the narrative's plausibility, improving the clarity of the narration, and evoking feelings in the viewer (Cuadrado et al. 2020). In many ways, sound design is a technical art form. Complex systems are frequently used to create, record, and edit sounds with specialized hardware and software. It includes all non-compositional components of a film, video game, or product sound project (Dakic 2007). Sound designers are skilled at using physical and mathematical knowledge to analyze and model space structure while considering sound effects. They can manipulate the design of natural or virtual space (Ozcan and Van Egmond 2008: 306/9). As a result, sound designers must deal with numerous design and development processes.

2.4.1 Sound Design in Film Theory

Sound involves identifying, acquiring, or creating auditory elements using sound production techniques and tools. Sound design often involves editing pre-created or recorded sounds, such as sound effects and dialogue, for the medium. Sound design, widely used in environments such as video games, films, television, and radio, is based on making sounds aesthetic, understandable, and familiar to the human ear (Dakic 2007: 1). Dakic (2007), asserts that sound had a grammatical role in the production of movies. Additionally, it asserts that movies have a sense of continuity or connective tissue. Dakic (2007: 3), explained the basic features of the sounds in movies as follows. (1) Hyper-reality and (2) correlation with a picture. In hyper-reality, the sound effects used in film and television often exaggerate reality. The soundtracks seem overrated when heard in isolation, but when viewed in the context of the film, they take on a more natural balance. In correlation with a picture frequently influences the sound. Depending on how sound is used, scenes can differ. The sound significantly impacts the narrative and the movie's rhythm (Dakic 2007: 3). Sound has two main roles in the film industry: storytelling and story support. Storytelling, possible in the film using dialogues, monologues, or off-narration, is the most significant aspect of movies produced in the "sound era." The sound effects used to support the narrative contribute to the tension in the movie and give the audience emotional cues. The fundamental components that make it possible are unique sound effects and the music (Dakic 2007).

Adaptation of sound design methods used in the film industry to other design disciplines is primarily encountered in industrial product design. Considering the sound design studies, models, and adaptations of industrial product design, which are widely used in the film and video game disciplines, two types of sound classification methods were discussed. These two methods classify sounds as diegetic/non-diegetic and intentional/consequential. On the other hand, the sound whose source is in the fictional world is diegetic. Some examples of diegetic sounds are the characters voice, the sounds emitted by the story's objects, and the melodies produced by the instruments, tape players, or radio that are visible in the scene. Non-diegetic sounds are external to the story universe (Susini et al 2014).

2.4.2 Product Sound Design

The Product Sound Design discipline emerged in the early 90s and is actively used, especially in the automotive industry. The interaction between people and products is increasing day by day. It is an emerging, interdisciplinary field with roots in acoustics and product sound quality (Ozcan and Van Egmond 2008). Product sound design is essential to balance the functional, aesthetic, and instructive qualities of sounds generated by our everyday tools, devices, and systems. Industrial and interaction design principles also influence product sound design. A product results from a design process that begins with a design challenge, progresses through ideation stages, and culminates in a market launch. Ozcan and Van Egmond (2006: 3) defined product sounds as the sounds produced by products due to their functionality.

Product sound design categorizes product sounds as consequential and intentional. Usually, a loudspeaker is used to produce intentional sounds. Most are digital and frequently appear in user interfaces (e.g., alarm clocks, cell phone button beeps, microwave ovens). Computer software or sound synthesizer hardware are typically used to produce these synthesized or recorded sounds (Ozcan and Van Egmond 2008). Consequential sounds, on the other hand, are emitted by products because of their function. For instance, hair dryers, vacuum cleaners, and washing machines are considered consequential sounds in industrial design. Consequential sounds are often informative about the working cycle of the product, and listeners cannot interfere with their formation (Ozcan and Van Egmond 2008; Susini et al. 2014).

2.5 TAXONOMY OF THE SOUND SOURCES

This chapter explains the classification methods of sound sources used in the soundscape, film theory, and product sound design in the literature. First, the classification methods in the soundscape approach were examined and explained with the studies in the literature. Then, the sound classification methods used in the film and video games industry are examined and explained. Finally, classification methods in product sounds, widely used today, are examined and explained.

Sound sources are design elements that designers should manage or position. However, sound sources must be categorized using empirical techniques before being used as a design element in the design process. The methods for categorizing sound sources in soundscape, film and video games, and industrial product design are explained in the following section.

2.5.1 Sound Source Taxonomy in Soundscapes

The sound classification method is a semantic schema that presents a knowledge map (Schafer 1977) . Proper classifications must be detailed, predictable, and understandable to meet specific requirements.

Designers should consider sound sources in the auditory environment as design elements that must be carefully created, managed, or positioned. However, for sound sources to be used as a design element in the design process, they must first be classified by experimental methods.

There were several research on the study of soundscape, and most of the sound classification methods in the literature are based on the work of Schafer (1977) which forms the basis of the sound environment. Brown et al. (2011) described soundscape classification under two main categories, indoor and outdoor. These two mains' categories are divided into a series of sub-categories. Sounds existing or created indoors can be man-made, industrial, or product based. The sounds that exist or are created outdoors are man-made, mechanical, transportation, urban, and natural sounds (Figure 6) (Brown et al. 2011: 390). To Brown et al. (2011: 390) the framework they presented today, the sound sources found in the built environment are classified under the soundscape subject and as recommended in the relevant standard (International ISO 2018).

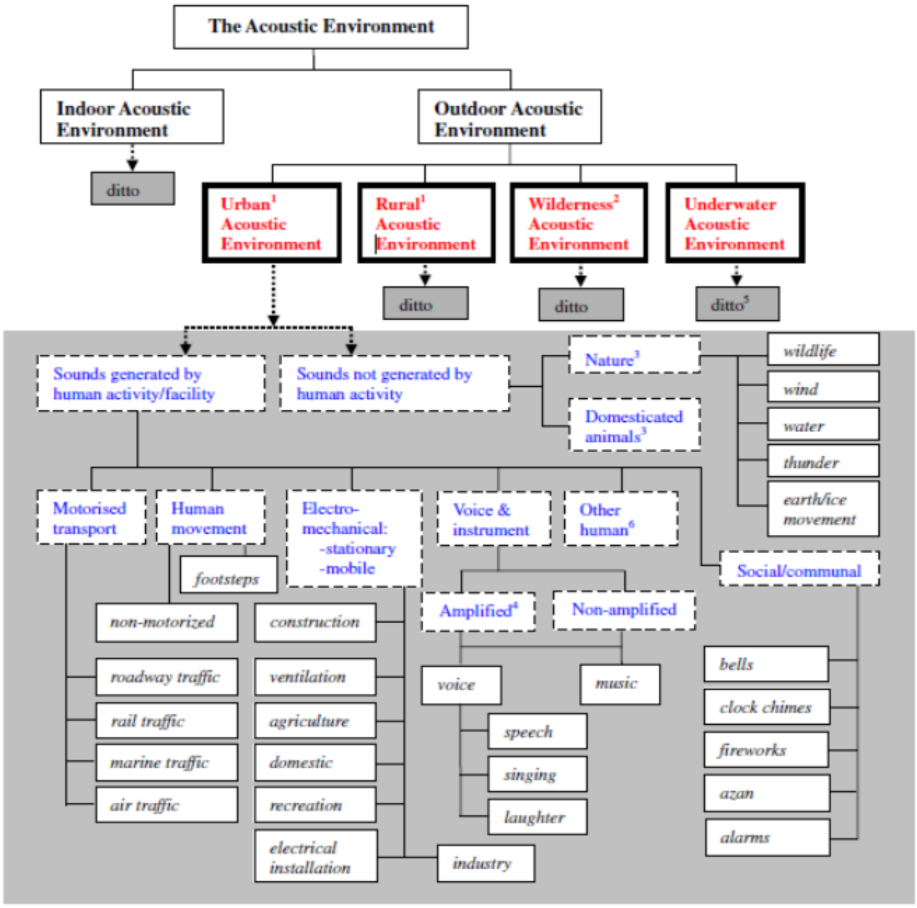

Figure 6: A possible taxonomy of the acoustic environment. (Brown et al. 2011: 390)

In addition, other research focuses on indoor and outdoor soundscapes. Although there are numerous techniques for classifying sound sources, the semantic differential method, which combines factor analysis with basic orientations to show orientations, and cluster analysis, which identifies groups of similar sounds based on attribute scales, are the most frequently used in the soundscape literature (Bones et al. 2018). Bones et al. (2018) investigated the classification of everyday sound sources in the soundscape literature. Each study interpreted sound source taxonomies differently and created a classification accordingly. Lafay et al. (2018) presented a new experimental protocol to study the mental representation of the urban soundscape. This study revealed the benefits of perceiving and scientifically interrogating the soundscape. Ercakmak and Dokmeci Yorukoglu (2020) presented a proposal regarding the indoor sound source taxonomy of indoor public spaces as a result of their soundscape and sound source preference analysis on shopping malls.

2.5.2 Sound Source Taxonomy in Film Theory

Considering the sound design studies, models, and adaptations of the industrial product design discipline, which are widely used in the film and game sectors, two types of sound classification methods come to the fore. Sound source classification methods in films and video games aim for sociocultural, contextual, and geographical coherence in spaces. Diegesis is based on the classification of diegetic and non-diegetic sounds used in film and video game theory. It is a film's storyline and temporal setting. Diegetic refers to every component of the movie's story universe, while non-diegetic refers to outside the story universe (Dakic 2007: 3). Most films tell a story. This narrative takes place in a fictional setting created for each movie. It makes no difference if the story is set in a fantasy world, a historical or a future world, or even if it is a documentary that depicts reality (Dykhoff 2012). In the real world, it can be assumed that every sound is diegetic. However, the context of a space is definitely dependent on its user and function. Hence, when an individual is unfamiliar with the surroundings or when the environment's purpose is incongruent with its design, unfamiliar sound sources can be classified as non-diegetic sounds. The key differentiation between diegetic and non-diegetic sounds in a built environment is the coherence between the physical environment, its purpose, and the sound sources (Susini et al 2014).

2.5.3 Sound Source Taxonomy in Product Design

The industrial product sound design classifies product-generated sounds as intentional and consequential sounds (Ozcan and Van Egmond 2006, 2008). Sound designers are responsible for creating and managing intentional sounds, and the extent of their influence on a particular sound source can be identified by examining the intention variable for that source (Ozcan and Van Egmond 2006). The sound designer determines the boundaries of their control over these sources, and consequential sounds often provide information about the functioning cycle of a product that listeners cannot intervene with. Examples of such sounds include the finish bells of microwave ovens, alarm clocks, and oven-setting feedback sounds. Additionally, product sounds can be categorized into six perceptually different categories: air, alarm, cyclic, impact, liquid, and mechanical sounds. The spectral-temporal composition, material interactions that produce sound, and conceptual associations of sounds within these categories vary. Moreover, the perceived character of a sound can depend on both perceptual and cognitive factors (Ozcan and Van Egmond, 2008).

The product's formal characteristics, such as cavities, holes, and the shape of the reinforcements, as well as its material characteristics, such as wall thickness and propagation speed, affect how much sound is generated in the product (Benli 2015). With this, Langeveld et al. (2013) identified the absence of comprehension concerning the connection between product sound and physical product attributes, such as sound transmission qualities of materials utilized in products, or the acceptable range of tolerances employed in manufacturing procedures. This knowledge gap is particularly pertinent to the design process of consequential product sounds.

2.6 KEY STUDIES

This section examines film, video game, and product sound design studies in the literature. Also, the section examines the studies used in the literature for sound classification methods in the soundscape approach.

2.6.1 Sound Design Studies in Film and Video Game Theory

The literature review showed that many models are aimed to be used for sound design in films and video games. The Dense model proposed by Walter Murch, which has a vast place in the literature, is used for film sound design (Figure 7). In this model, the sound sources are located on a single axis with shaped-coded endpoints. Sound carries either an intense emotion like music, a code like language and speech, or a semiotic meaning between the two extremes (Jarrett and Murch 2000).

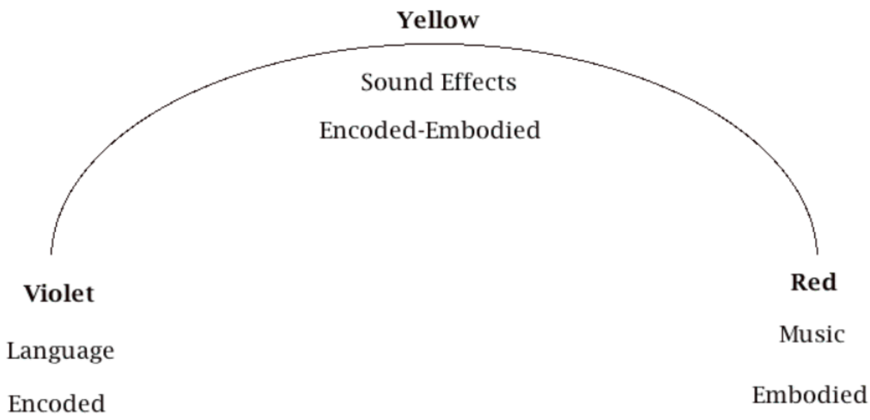

Figure 7: Dense Model by Walter Murch. (Jarrett and Murch 2000)

The fiction of video games, which overlaps with virtual reality and glorifies user interaction, presents the models closest to the built environment. The first of these models is the IEZA model (Figure 8) (Tol and Huiberts 2008). The IEZA model uses two dimensions to classify sounds in video games. The first dimension distinguishes between sound coming from the fictional game world, such as the footsteps of a game character, and sound coming from outside the fictional game world, such as music. The second dimension indicates whether the player interacts with the character they control or the user interface.

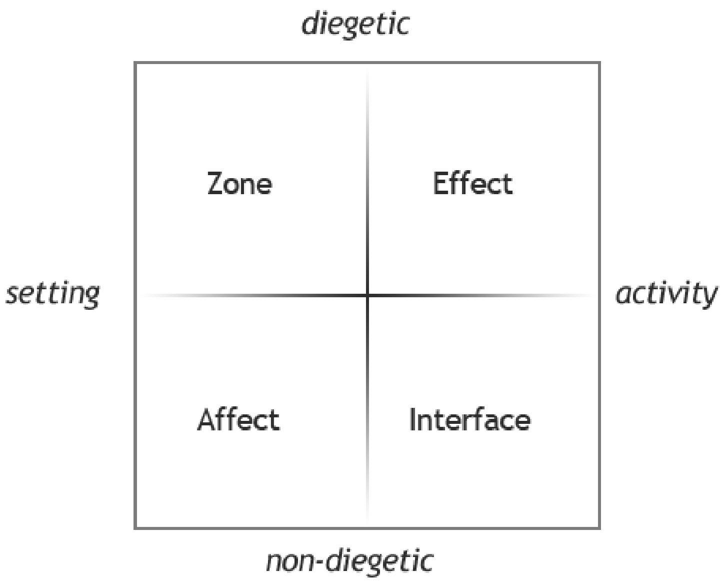

Figure 8: The IEZA Framework for Video Games. (Tol and Huiberts 2008)

2.6.2 Sound Design Studies in Product Design

To Ozcan and Van Egmond (2006) absence of a systematic methodology to coordinate sound-related design activity is the main weakness in product sound design. Additionally, sound designers lack the resources to communicate their ideas and convey information about the intentional product sound. On the other hand, product sound design can use techniques from product design. The model they presented interactions between the designers engaged in the product development process are organized in Figure 9.

Ozcan and Van Egmond (2006) define design processes in four stages (Figure 9). The initial stage in the sound analysis procedure is to ascertain the timing and manner in which the product generates sound, as well as how the sound is integrated into the interaction between humans and the product. Designers start conceptualizing the new product sounds that will be created once the conceptual and practical issues with product sounds have been identified during the sound analysis phase. The embodiment process starts when designers first hear the noises made by the device during the design and development of a new product.

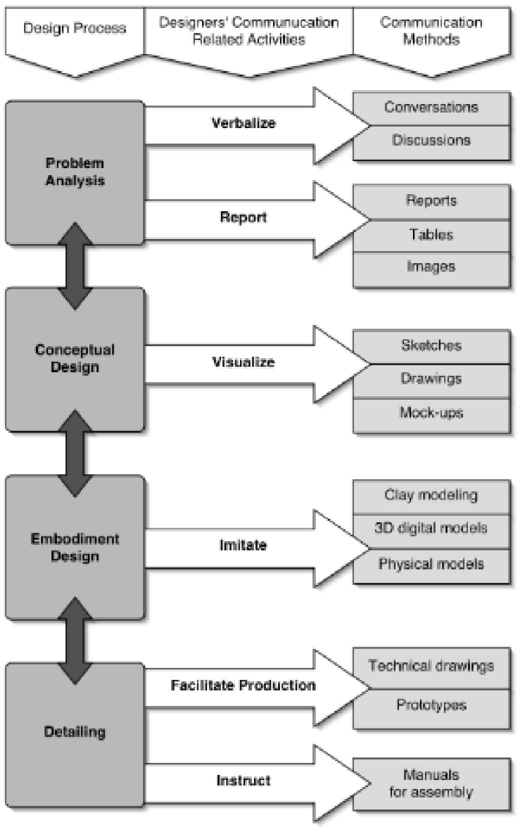

Figure 9: Design process, designers' communication related activities, and communication methods. (Ozcan and Van Egmond 2006)

Another study in literature, Langeveld et al. (2013) four main components of the model sources, sound transmission through the product, radiation, and transmission to the receiver are on product sound design. This model distinguished between sounds the product involuntary sounds produced and sounds the product caused (Figure 10). When applied, this model accomplishes two goals. First, to apply their findings from investigations into the physical, perceptual, and emotional domains to a modified product design. The second objective is to understand how sound is produced in products and listened to by people (Langeveld et al. 2013: 53).

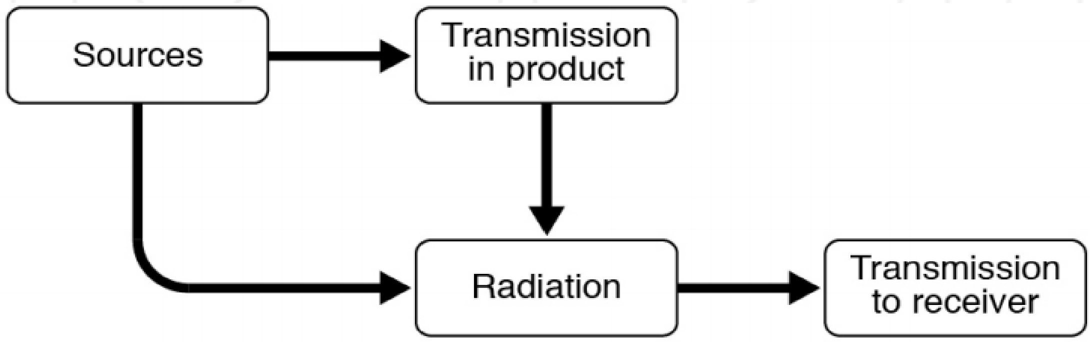

Figure 10: Model for product sound. (Langeveld et al. 2013: 53)

Langeveld et al. (2013: 53) outlined four stages of the product sound design process. (1) Creating product prototypes, (2) conducting a sound analysis in the context of the product's use, (3) creating sound sketches to conceptualize ideas, and (4) describing the sounds produced by their intended use in detail. Once conceptual and functional issues with product sounds are identified during the sound analysis phase, designers can then move on to developing new product sounds that need to be implemented. The embodiment phase is the initial period designers are exposed to sounds coming from a newly designed product after the design and construction of the products. The product sound is adjusted during the final detailing stage. The final prototype is constructed at this point, giving the finished product its final form (Langeveld et al. 2013).

2.6.3 Soundscape Taxonomy Studies

Designers must consider sound sources in the acoustic environment as essential design elements that require careful creation, management, or positioning. Empirical methods should be used to classify sound sources as design elements during the design process. To classify sound sources effectively, three key features must be analyzed, and each feature can be evaluated as a separate classification layer. The first layer involves categorizing sound sources into types that have been widely researched in soundscape studies. Currently, the acoustic elements of the built environment are usually classified within the scope of soundscape, as recommended by relevant standards (ISO 2018).

Although many methods can be used for the classification of sound sources, the most widely used methods in the auditory landscape literature are the semantic differential method, which is used with factor analysis to reveal basic orientations, and cluster analysis, which is used to identify similar sound groups in terms of feature scales (Bones et al. 2018). Bones et al. (2018: 10) investigated the classification of everyday sound sources in the soundscape literature. In this study, the soundscape taxonomy is generated by hierarchical cluster analysis of the principal dimensions resulting from correspondence analysis (Figure 11).

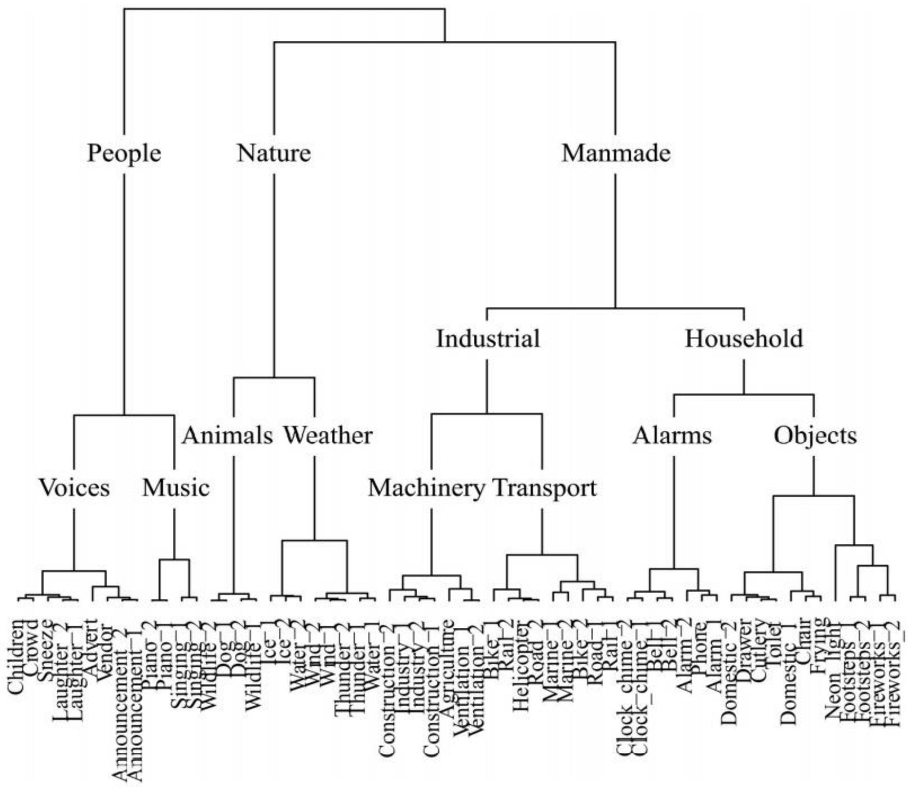

Figure 11: Hierarchical cluster analysis of soundscape taxonomy. (Bones et al. 2018: 10)

The nature taxonomy is generated by hierarchical cluster analysis of the principal dimensions resulting from correspondence analysis. All five exemplars of each sound were categorized together, except for the case of ambient, where two exemplars were categorized together in a category by the same name, and three were categorized as forest sounds (Figure 12) (Bones et al. 2018: 11)

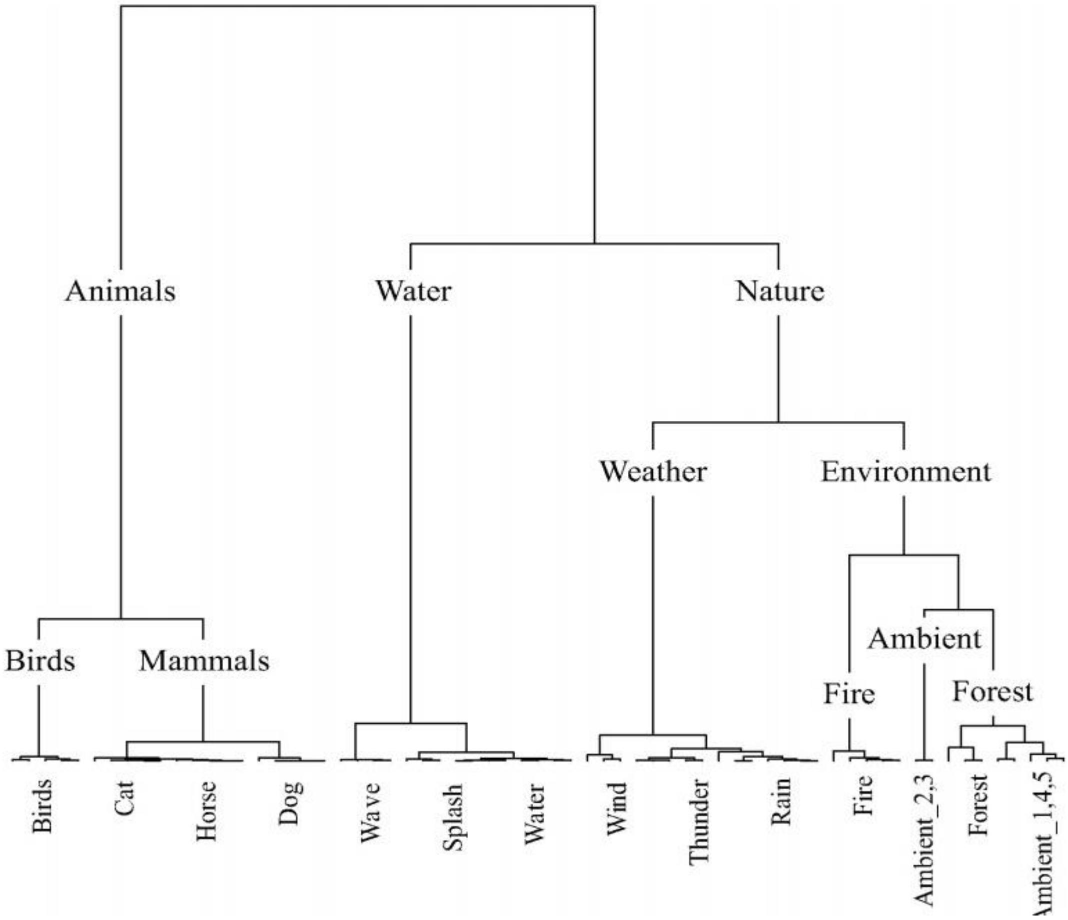

Figure 12: Hierarchical cluster analysis of the nature soundscape taxonomy. (Bones et al. 2018: 11)

Manmade taxonomy classification generated by Bones et al. (2018: 12) by hierarchical cluster analysis of the principal dimensions resulting from correspondence analysis. In all cases, all five exemplars of each sound were categorized together (Figure 13).

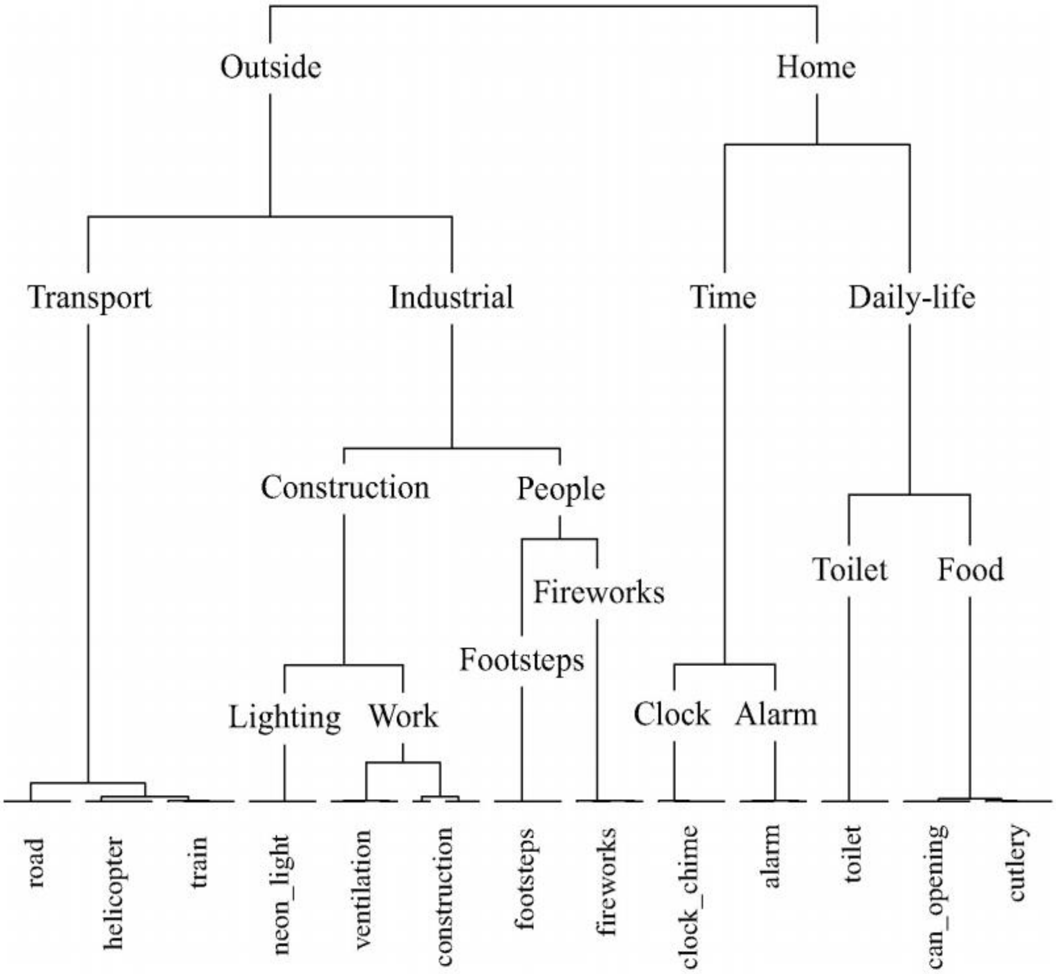

Figure 13: Hierarchical cluster analysis of the manmade soundscape taxonomy. (Bones et al. 2018: 12)

Lafay et al. (2018) presented a new experimental protocol to study the mental representation of the urban soundscape. This study revealed the benefits of perceiving and scientifically interrogating the soundscape (Figure 14).

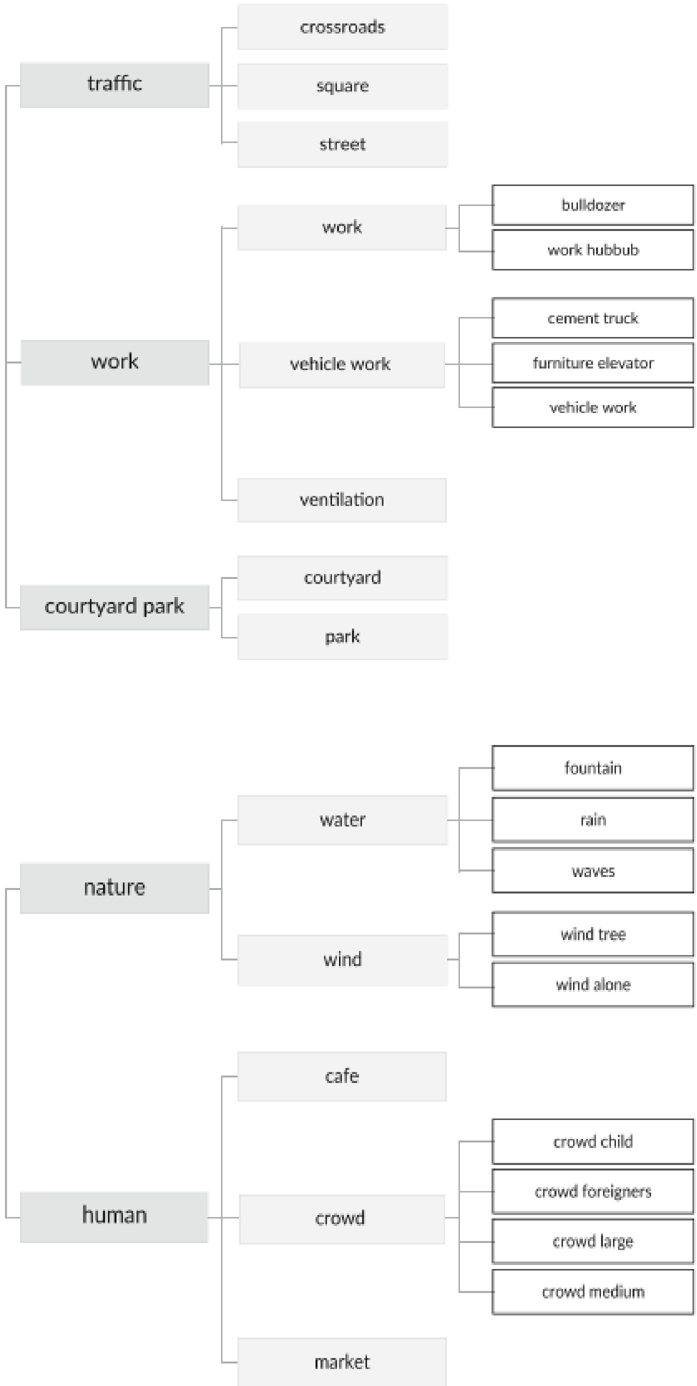

Figure 14: Urban soundscape taxonomy. (Lafay et al. 2018)

Ercakmak & Dokmeci Yorukoglu (2020) presented a proposal regarding the indoor sound source taxonomy of such closed public spaces as a result of their soundscape and sound source preference analysis on shopping malls (Figure 15).

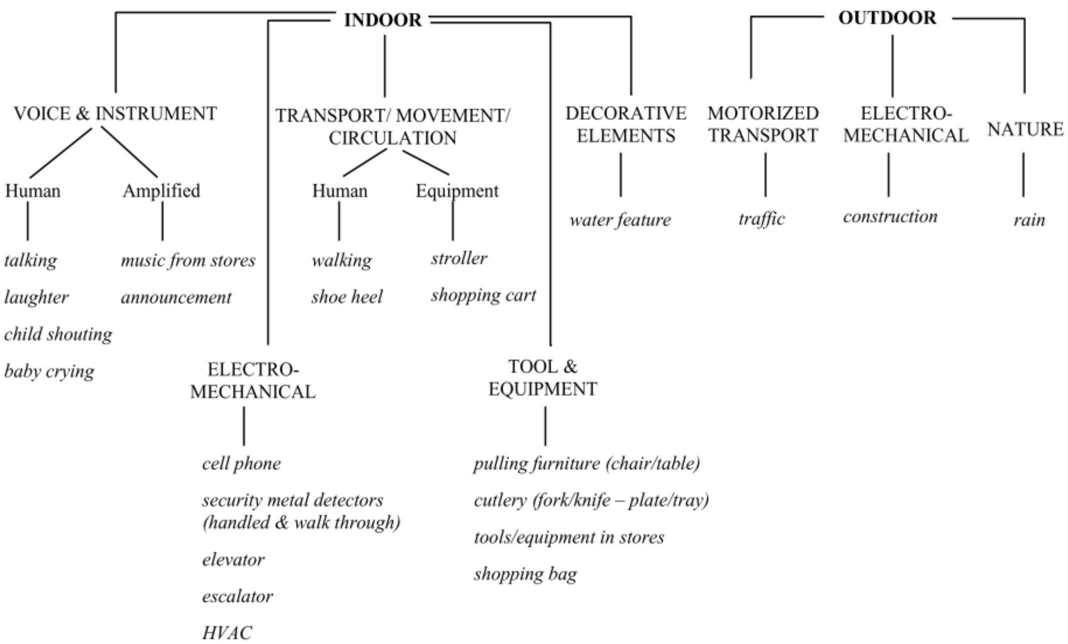

Figure 15: Proposed taxonomy for shopping centers with the identified sound sources. (Ercakmak and Dokmeci Yorukoglu 2020).

According to Lindborg (2016: 297), restaurants provide an excellent opportunity to study sound perception in real-world settings because they are a type of environment called a service scape, which refers to the physical surroundings created by humans. Restaurants are complex environments that are affected by various physical and psychological factors, such as temperature, lighting, noise, music, scent, memories, and emotions. The interactions between customers and employees also contribute to the sensory experience. Overall, restaurant sensory effects are typically perceived as a whole and only become problematic when extreme, persistent, or do not align with people's expectations (Lindborg 2016). Lindborg (2016) created a questionnaire to examine how customers behave and perceive the restaurant environment. The questionnaire had a section where participants could write down any sounds they heard in the restaurant. The questionnaire also asked respondents to describe three characteristic sounds of the restaurant and to provide five words to describe the restaurant to a friend. Additionally, the questionnaire included a question from the SSQP asking participants to rate their agreement with statements about their experience of the restaurant's sound environment. These three items were relevant to the current study. As illustrated in Figure 16, the Sound and Source taxonomies were treated at intermediary levels.

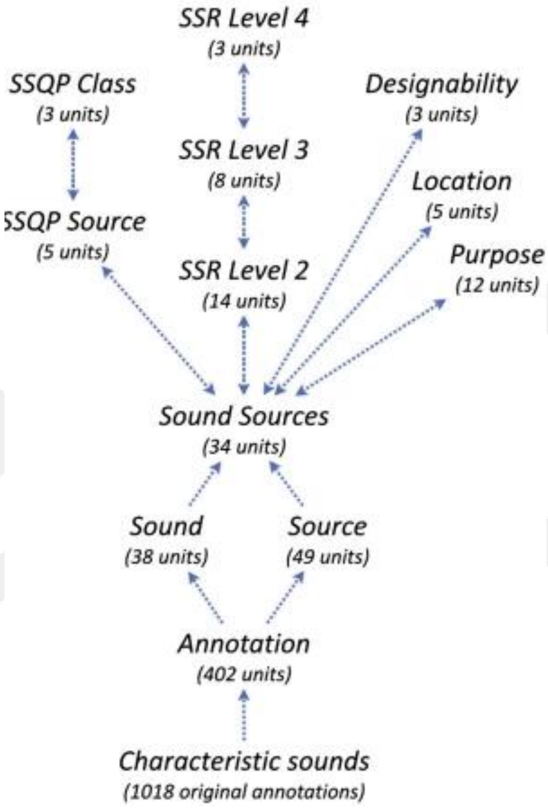

Figure 16: Overview of units and levels developed in the. (Lindborg 2016: 301)

2.7 DISCUSSION

In this section, relevant topics in the literature are explained and supported by previous studies found in the literature to support the studies planned for the realization of this thesis. First, definitions of architectural acoustics and physical characteristics of sound were initially described. Then, the urban and indoor soundscape approaches were explained. Later, the concept of sound design in film theory and product design, one of this thesis's main aims, was described. Finally, the sound classification methods of sound sources were examined and explained with the support of previous studies in the literature.

First, the physical characteristics of sound are discussed in this section. Sound, a type of energy, can move quickly and contain large distances at atmospheric pressure. These alterations are specifically brought on by objects vibrating in wave motions. The first of sound's three fundamental physical characteristics is measured in frequency hertz (Hz). The wavelength, the size at which a periodic wave repeats itself, is the second physical characteristic of sound. The distance at which a vibrating object or a point on the wave moves with its equilibrium position is described by the third and final physical property, amplitude. Today, architectural acoustics and soundscape are the disciplines that examine auditory designs of spaces, and studies in the literature are interdisciplinary. The generation, transmission, and propagation of a sound source indoors and within structures are all considered to be components of architectural acoustics. Room acoustics ensures that all listeners get the best out of the sound source at the volume level. The goal of studying building acoustics is to establish how sounds from inside or outside the building enter different building components. Room acoustics significantly impact people's daily lives. Schroeder (1980), asserted that proper application of the architectural acoustics discipline could raise peoples' quality of life (Schroeder 1980).

After the physical characteristics of sound and architectural acoustics, the soundscape approach was reviewed. The soundscape approach, developed by Schafer (1977), is a framework for integrating perceptual components and the acoustics of a space. A group of sounds in a location and how those sounds are perceived collectively are referred to as a soundscape. Therefore, current soundscape research considers and covers the physical and perceptual characteristics of the aural environment. The soundscape approach has been examined in the literature in two subjects: urban and indoor. With the existing studies in the literature, the urban soundscape is explained by the fact that many sound sources in urban sound environments have physical and semantic characteristics determined by the geographical and socio-cultural context of a particular environment. On the other hand, the architectural characteristics of indoor acoustic environments and human perception are examined to explain indoor soundscapes.

The sound design discipline, which is at the center of the film and video game industries, is explained and discussed after the urban and indoor soundscape approach and is supported by studies in the literature. According to Dakic (2007), sound design is a technical art form in many ways. Complex systems are frequently used with specialized hardware and software to create, record, and edit sounds. It includes all non-compositional elements of a sound project for a movie, video game, or product.

Sound in the film industry serves two main purposes: to tell and support stories. The most important element of movies made during the "sound era" is storytelling, which can be accomplished in a picture using dialogue, monologues, or off-narration (Dakic, 2007). Product sound design is crucial to balance the instructive, esthetic, and functional aspects of the sounds produced by the systems, tools, and tools we use daily. Industrial and interaction design principles have an impact on product sound design as well. A design process that starts with a design challenge, moves through ideation phases and ends with a market launch to produce a product. According to Ozcan and Van Egmond (2006), product sounds are the noises that products make due to their functionality.

Finally, the classification methods of sound sources are discussed. Three topics, soundscape, film theory, and product design, examine sound source classification methods, which are explained using literature studies as examples. In their study, Brown et al. (2011) divided the classification of soundscapes into two categories: indoor and outdoor. There are several sub-titles within each of these two main titles. Man-made, industrial, or product-based sounds may be present or produced indoors. Man-made, mechanical, transportation, urban, and natural sounds can be heard or made outside. Film and video game sound source classification techniques aim for spatial coherence regarding sociocultural, contextual, and geographic factors. The classification of diegetic and non-diegetic sounds used in video games and film theory is the foundation for diegesis. Dakic (2007), states that diegesis refers to a film’s narrative and context. Non-diegetic refers to everything outside the story universe of the film, whereas diegetic refers to everything inside the story universe. According to Ozcan and Van Egmond (2006,2008), industrial product sound design classification product-generated sounds as intentional and consequential sounds.

2.8 CONCLUSION

This study aims to present a sound design guideline for architects by adding a new classification method to the soundscape literature's existing sound source classification methods. First of all, the existing studies in the literature were examined and architects. Within the scope of the present study, experiments were carried out in three spaces with different functions to verify the environmental sound design model developed. The developed environmental sound design model is explained in detail in Chapter 3. Detailed information about the selected venues (Chapter 4.2.1), experimental methods of listening tests (Chapter 4.2.2), and the results of the experimental processes (Chapters 5.2 and 5.3) are explained in the following chapters.

CHAPTER III

ENVIRONMENTAL SOUND DESIGN MODEL

Sound design is at the center of the film and video game disciplines and has been overlooked in the architectural literature. In the sound design discipline, sound layers such as effects, music, and dialogue are often synthesized or recorded in movies and video games. If a person hears a sound, that sound source was deliberately designed or recorded. The sound design carries emotion, meaning, and information. What is expected in sound design in the field of architecture is to convey emotion, meaning, and information. Every sound and visual element in the built environment should be shaped with the foresight and knowledge of the designer. Since the primary purpose of this thesis is to present a new proposal to the sound source classification methods in the literature in the field of architecture in the field of sound design, which has an important place in the film and video game sectors, the sound elements in the creative environment, an environmental sound design model have been developed. It aimed that the developed sound design model will help architects and designers to classify the sound elements in the built environment depending on the functions of the spaces (Kitapci and Ozdemir 2021a).

The environmental sound design model presented in this thesis is based on the methods called Diegesis and Intention, derived from film, video games, and product-based sound design theories. These two sound design theories are explained detail in Section 2.5.2. It is possible to categorize every sound source in the built environment as dietetic sound. Since the phenomenon of the audience in movies and video games is not present in the built environment, the treatment of non-diegetic sounds in the constructed environment can only be analyzed according to the functions and contexts of the spaces. The users of the spaces have a direct impact on the functions of the spaces. Users may perceive unfamiliar sound sources as non-diegetic sound events if they are unaware of the story or the functional, geographical, or socio-cultural context of a sound architectural environment.

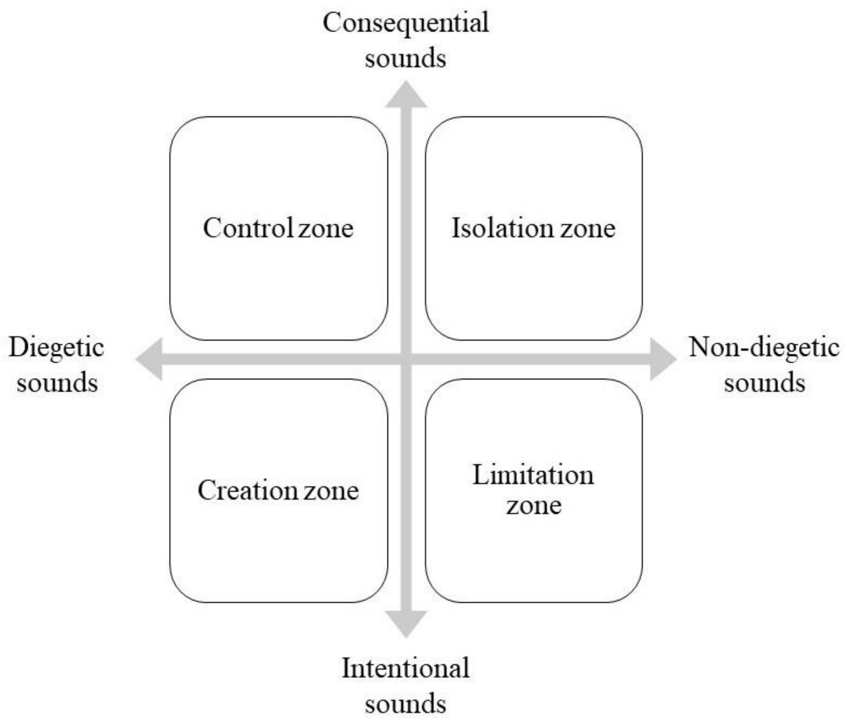

Figure 17: Proposed sound design model (Create, Limit, Isolate, and Control).

The X axis of the environmental sound design model represents diegesis, and the Y axis represents intention (Figure 17). Intention makes determining the designability of sound sources. If an ambient sound source is consequential, the sound designer may have limited control. If the environment's sound source is intentional, the sound designer can create the sound source completely. (Kitapci and Ozdemir 2021a). The sound design model is divided into four zones by the diegesis and intentional axes, which quantify the designability of a given sound source. The creation zone, limitation zone, isolation zone, and control zone are the four zones in the sound design model (Kitapci and Ozdemir 2021a).

The proposed environmental sound design model can be applied to every sound source available in the built environment. Diegesis and intention values must be defined before a specific sound source's location on the model can be determined. A 7-point scale determines the intention values of sound sources. The designer action corresponding to each score on the scale are presented in Table 2. In addition, diegesis values are required to determine the positions of the sound sources on the model. They are determined by the results of the listening tests.

Table 2: The intention values of sound sources and the designer action corresponding to each score in this scale.

Intention	The maximum impact of designer	Intention value
Intentional	Design from scratch	+3
	Full control by the selection of the product	+2
	Partial control by planning	+1
Neutral	Silence	0
Consequential	Partial control by the selection of the product or isolation	-1
	Full isolation or partial control	-2
	Uncontrollable	-3

The first zone in the sound design model is the limitation zone. Sound sources in this zone are non-diegetic and intentional; and therefore, should be limited by the designer. These sound sources are not recommended to be completely isolated since they may carry important contextual information. The second zone in the model is the isolation zone. For a sound source to be in the isolation zone, it must be a consequential and non-diegetic sound. The sound designer should completely isolate the sound sources located in this zone. The third zone in the sound design model is the creation zone. Any sound source located in this zone is diegetic and intentional. The zone typically contains digital or mechanical sound sources such as elevators, telephones, doorbells, and similar items is known as the functional zone. The sound designer should develop these sound sources in accordance with the contextual requirements of the space. The final zone in the sound design model is the control zone, which encompasses diegetic and consequential sound sources. The sound designer has minimal control over these sound sources, which must be consistent with the contextual aspects of the space. For example, a sound designer may indirectly influence footstep sounds by modifying the type of flooring used in a limited capacity. The environmental sound design model proposed in this thesis aims to guide architects and other environmental designers throughout the design process by considering the sound source, the context of the space, and the designability of sound sources. Within the scope of the first main phase of the thesis, it is based on the sound design model, collecting sound sources from three different types of venues: (1) restaurants, (2) open offices, and (3) urban spaces.

CHAPTER IV

METHODS

The methods implemented to verify the proposed sound design model were constructed in two experimental phases. In the first phase, environmental sound recordings were collected from the selected venues, the collected sound recordings were examined, and the sound sources in the soundscape of the venues were identified and listed. Then, web-based listening tests were conducted with 32 participants. In the second and final phase, sound design experiments were carried out with 80 participants.

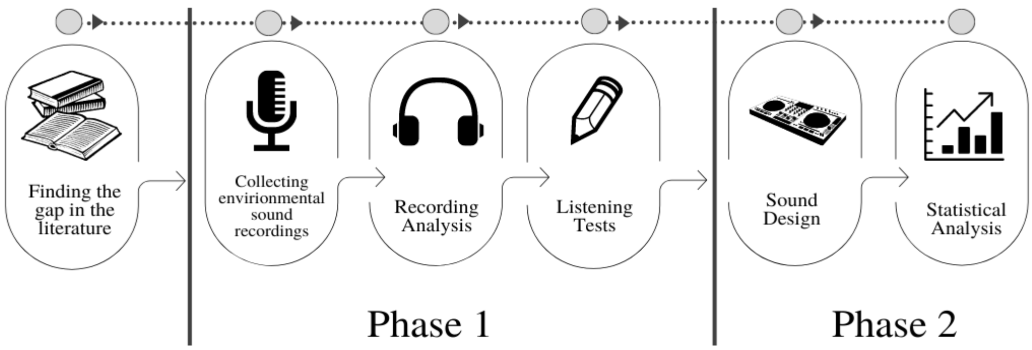

Figure 18: Phases of the studies carried out within the scope of the thesis.

4.1 STUDY DESIGN

Environmental sound recordings were collected from two different restaurants (Big Chefs and Coffee Craft Town), an open-plan office (Ace Mimarlık), and an urban space (Tunalı Hilmi Street) in the Cankaya district of Ankara. Big Chefs is an Ankara-based restaurant chain founded in 2007. It has 51 branches throughout Turkey and welcomes approximately seven million guests annually. Coffee Craft Town was established in 2016, and the Ace Mimarlık office was established in Ankara in 1985. Ace Mimarlık's office has a ground floor and two basement floors. The building has total area of 1350 m². In Kuğulu Park, environmental sound recordings were collected from three different zones. Kuğulu Park is a 1st Degree Natural Protected Area with 7743 m².

These two restaurants were chosen because many customers use them during the day, the human traffic in the spaces is high, and the types of sound sources in such environments are diverse. Ace Architecture was chosen because of the presence of many types of humans, products and mechanical sounds and the human traffic created by office workers during the day. Although Kuğulu Park is in the city center, where the population density is very high, it attracts more users than other parks, and it was preferred because of the intense city traffic and user diversity in the park.

The sound recordings at the Big Chefs were collected from six zones: three indoor and three outdoor. The sound recordings at the Coffee Craft Town were collected from four zones: one indoor and three outdoor spaces. The sound recordings in the Ace Mimarlık office were collected from two indoor zones.

4.2 PHASE 1: COLLECTING SOUND SOURCES AND LISTENING TESTS

This section explains the recording process of sound sources from selected venues, and web-based listening tests. Section 4.2.1 explain collecting sound sources from selected venues. Furthermore, Section 4.2.2 contains demographic information about how the listening tests are administered and about the participants.

4.2.1 Collecting Sound Sources from Selected Venues

The sound recordings were collected during the working hours of the selected venues and at the time intervals when the user population was the highest (Figure 19). Sound recordings were recorded with a Zoom SGH shotgun microphone and Zoom XYH-6 unidirectional X/Y type microphone adjusted to a recording angle of 120 degrees, at 96 kHz and 24-bit quality. Shotgun type microphone was used to record the individual sound sources, and an X/Y type microphone was used to record the environmental. The sound recorder and the microphones were positioned 140 cm above the ground on a tripod. The collected sound recordings underwent post-production using the Ableton Live 11 Suite Digital Audio Workstation (DAW) program. The Beyerdynamic DT770 Pro (80 ohms) closed-cap isolated headphones used for the analysis were connected to the Focusrite 2i2 third-generation audio interface. Each sound source identified in the audio recordings was listed in detail. Each sound recording is fifteen minutes long. In restaurants, the audio recordings were collected from ten different recording points in each zone to ensure the variety of audible sound sources. The sound recordings were gathered from a single recording point in the open office setting. In the urban area, the audio recording were collected from three recording points. These locations were selected due to their high pedestrian traffic, regular daily use, and wide variety of sound sources.

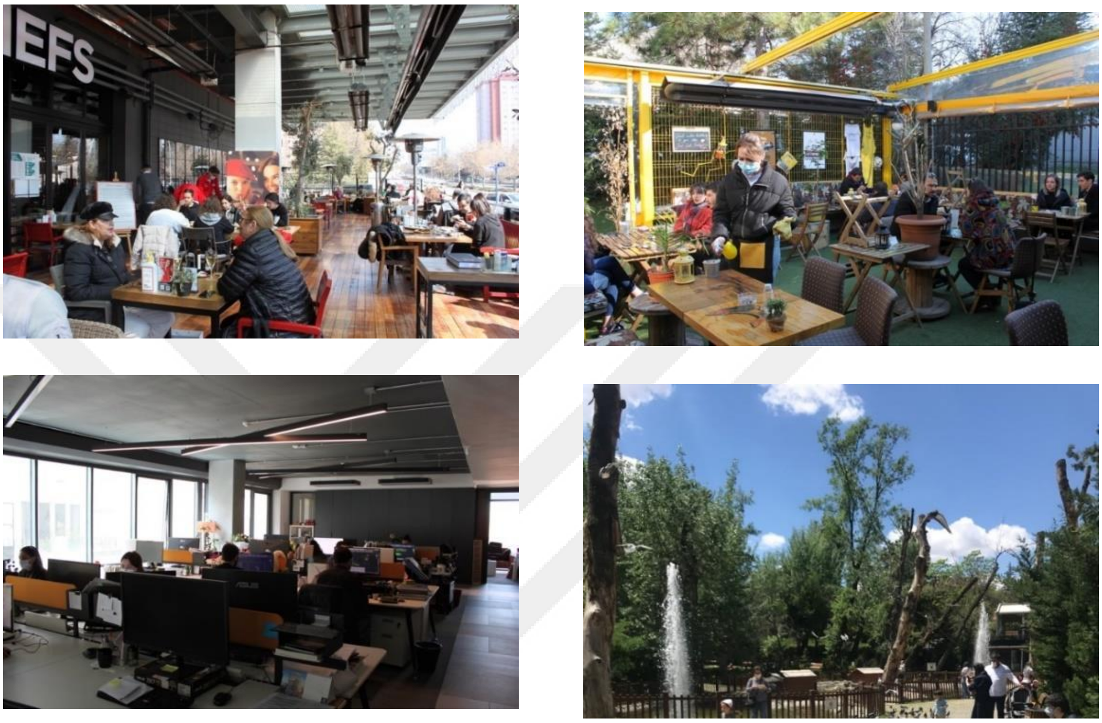

Figure 19: The places where the sound recordings were collected are (top left) Big Chefs, (top right) Coffee Craft Town, (bottom left) ACE Mimarlık, (bottom right) Kuğulu Park.

4.2.2 Listening Tests

In the listening tests, the participants were asked to identify the sound sources and to determine the sound sources' diegesis values. Sound recordings from all three spaces were examined in the first phase of the experimental phase of the study, and a comprehensive list of environmental sound sources in the recordings was produced (Table 5.6.7 and 8). After analyzing the sound recordings, each of the listed sound sources was chosen from the International Affective Digitized Sounds-Extended (IADS-E) (Yang et al. 2018) database for the listening tests. Each sound file was standardized to 6 seconds. Due to the Covid-19 pandemic disease that occurred worldwide when the listening tests were to be carried out, the tests were carried out on a web-based instead of face-to-face. The web-based listening tests aimed to identify the diegesis values of the sound sources that has been identified and listed. The Web

Audio Evaluation Tool (Jillings et al. 2015), widely used in research on sound source identification, was used to create the listening tests. As this tool is internet-based, the participants were not required to install additional software. They were asked to specify the type of sound system they used (in-ear/over-ear headphones, an external speaker, or a laptop speaker). The tool can also normalize frequency and sound pressure level based on the listeners' preferences for in-ear/over-ear headphones, external speakers, or laptop speakers. The participants' demographic information was gathered before the listening tests (Table 3). Of the total 32 participants, %25,6 are between the ages of 18-24, %28,8 are between the ages of 25-34, %19,2 are between the ages of 35-44, % 19,2 are between the ages of 45-54, and %7,2 are between the ages of 55 and more. Female participants make up %64 of the group, and male participants are %36. It was seen that the participants were mainly architecture and interior architecture students, architects, and interior designers. In total, it was seen that ten participants used in-ear headphones, seven participants used over-ear headphones, eight participants used laptop speakers, five participants used external speakers, and finally, two participants used other speaker.

Table 3: Demographic information about who participates in listening tests.

Participants	Gender	Education	Sources	Job	Location	Age
1	Female	Undergraduate Degree	Laptop Speaker	Interior architect	Ankara	25-34
2	Female	Ph.D. Graduate	External Speakers	Architect lecturer	Ankara	55 and older
3	Male	Ph.D. Graduate	Other	Lecturer	Ağrı	45-54
4	Female	Secondary School Graduate	In-Ear Headphones	Student	Ankara	18-24
5	Female	Undergraduate Degree	In-Ear Headphones	Interior architect	Ankara	25-34
6	Female	Undergraduate Degree	Laptop Speaker	Student affairs department head	Antalya	35-44
7	Female	Master’s degree	External Speakers	Public employee	İstanbul	45-54
8	Male	Ph.D. Graduate	Laptop Speaker	Interior architect	Ankara	45-54
9	Female	Undergraduate Degree	Laptop Speaker	Engineer	İstanbul	55 and older
10	Female	Secondary School Graduate	Laptop Speaker	Interior architect	Ağrı	18-24
11	Male	Secondary School Graduate	On-Ear Headphones	Student	İzmir	18-24
12	Male	Undergraduate Degree	Laptop Speaker	Officer	Elazığ	45-54
13	Female	Ph.D. Graduate	On-Ear Headphones	Academician	Ankara	35-44
14	Male	Undergraduate Degree	On-Ear Headphones	Lawyer	Ankara	25-34
15	Male	Undergraduate Degree	In-Ear Headphones	Architect	Ankara	25-34
16	Female	Undergraduate Degree	Laptop Speaker	Interior architect	Ankara	25-34
17	Female	Secondary School Graduate	In-Ear Headphones	Student	Bursa	18-24
18	Female	Secondary School Graduate	On-Ear Headphones	Interior architect student	Eskişehir	25-34
19	Male	Master’s degree	In-Ear Headphones	Officer	Hakkari	35-44
20	Female	Undergraduate Degree	External Speakers	Officer	Afyon	55 and older

Table 3 Continued

21	Female	Undergraduate Degree	On-Ear Headphones	architect	Ankara	18-24
22	Female	Undergraduate Degree	In-Ear Headphones	Research Assistant	Gaziantep	18-24
23	Female	Master’s degree	On-Ear Headphones	Interior architect	Ankara	25-34
24	Female	Ph.D. Graduate	In-Ear Headphones	Academician	Ankara	25-34
25	Female	Secondary School Graduate	In-Ear Headphones	Student	Bursa	18-24
26	Male	Master’s degree	External Speakers	Lecturer	Sivas	35-44
27	Female	Undergraduate Degree	In-Ear Headphones	Interior Architect, Graduate Student	Ankara	25-34
28	Male	Undergraduate Degree	Other	Head of Department	Erzurum	35-44
29	Male	Undergraduate Degree	Laptop Speaker	Interior architect	Ankara	35-44
30	Female	Secondary School Graduate	In-Ear Headphones	Interior architect student	Ankara	18-24
31	Male	Undergraduate Degree	On-Ear Headphones	University Administrative Staff	Kayseri	45-54
32	Male	Undergraduate Degree	External Speakers	Officer	Nevşehir	45-54

4.3 PHASE 2: SOUND DESIGN

In this section, the sound design experiment carried out for three different venues, the demographic information of the participants, the tools used during the sound design, and the statistical analysis methods of the sound design results are explained in detail.

4.3.1 Sound Design of Selected Venues

In the continuation of the second phase of the experiment, the soundscape designs of the three different venues (restaurant, open-plan office, and urban space) were carried out. Of the total 80 participants, 97.5% are between the ages of 18-24, and 2.5% are between the ages of 25-34, and female participants make up 87.25% of the sample group and 13.75% of male participants. With the aid of the soundscape design setup (Figure 20) set up in the building physics lab of the Çankaya University Faculty of Architecture building, the participants were asked to design the soundscapes of the given environments. Figure 20 presents the five main components of the ssoundscape design setup. Ableton Live Suite 11 software was used during the soundscape design. The sound output of the software was processed on the Focusrite Scarlett 2i2 external audio interface and transmitted to the designer via Beyerdynamic DT770 Pro (80 ohm) closed cap headphones with high sound quality. Control of the software is provided by Korg NanoControl 2 external midi control interface.

Figure 20: The soundscape design system consisting of five basic parts components.

Table 4: List of sound sources used in DAW software by sound channel.

	Channel 1 Background	Channel 2 Signal	Channel3 Signal	Channel 4 Signal	Channel 5 Signal	Channel 6 Signal	Channel 7 Signal	Channel 8 Signal
Restaurant	Restaurant exterior	Footsteps(Wood)	Ventilation-1	Traffic-1	Door - 1	Call bell-1	Chair dragging-1	Cash register-1
	Restaurant interior	Footsteps(Concrete)	Ventilation-2	Traffic-2	Door - 2	Call bell-2	Table dragging	Cash register-2
	Restaurant (Kitchen)	Footsteps(Carpet)	Ventilation-3	Traffic-3	Sliding door	Call bell-3	Chair dragging-2	Cash register-3
Open-plan office	Office interior-1	Footsteps(Wood)	Light switch-1	Coffee machine-1	Ventilation-1	Door-1	Office phone-1	Printer - 1
	Office interior-2	Footsteps(Concrete)	Light switch-2	Coffee machine-2	Ventilation-2	Door-2	Office phone-2	Printer - 2
	Office interior-3	Footsteps(Carpet)	Light switch-3	Coffee machine-3	Ventilation-3	Door-3	Office phone-3	Printer - 3
Urban Area	Park	Footsteps(Wood)	Fountain–1	Birds-1	Motorcycle-1	Car alarm	Traffic-1	Construction - 1
	Traffic	Footsteps(Concrete)	Fountain–2	Birds-2	Motorcycle-2	Police siren	Traffic-2	Construction - 2
	Fountain	Footsteps(Gravel)	Fountain-3	Birds-3	Motorcycle-3	Ambulance siren	Traffic-3	Construction - 3

Three sound sources were assigned to each of the eight audio channels created in the DAW software. Table 4 lists the sound sources assigned in each audio channel. While one sound channel were reserved for the background sound recordings, individual sound sources were assigned to the remaining seven audio channels. The audio files to be assigned to the seven signal channels were selected depending on the results of the listening tests. The sound files are normalized at -5 dB in post-production due to the varying sound levels of the audio files.

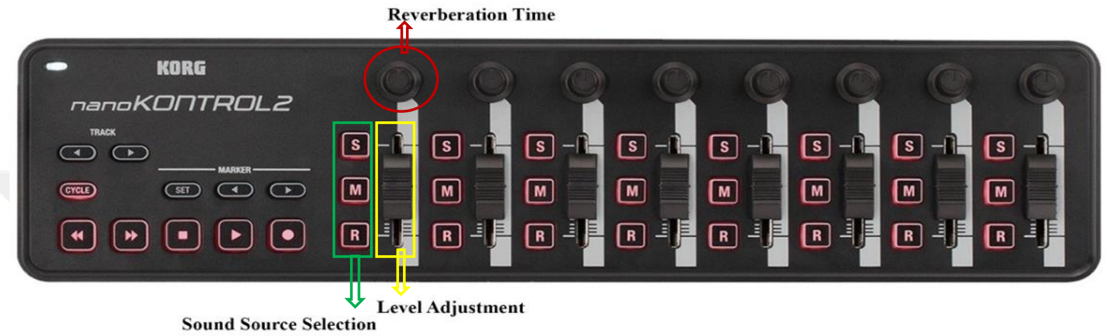

Figure 21: Function assignment key mapping diagram of the midi control interface controlling the DAW software.

The participants were asked to design the soundscapes for three different spaces, a restaurant, an open-plan office, and an urban area. They were requested to design the soundscape consistent with the presented photograph of the spaces. The photographs were presented via a computer monitor. The participants controlled the DAW software through a midi control unit. The buttons, potentiometers, and dial keys on the midi control unit were assigned to various DAW software commands. The S, M, and R keys on each of the eight channels of the midi controller were mapped to select and play the three different audio files assigned to the audio channels. The full key mapping diagram is shown in Figure 21. The experiment process was thoroughly explained to the participants before they began the design phase. No time limit was set on how long it would take to design the soundscape. The participants were allowed to try unlimited combinations of audio channels and sound sources. The participants completed the experiment by saving the sound source choices, sound levels of the audio channels, and the reverberation time.

4.3.2 Statistical Analysis

The data collected in the second phase of the study were analyzed statistically. The data sets obtained in the second stage were normalized using the modulus equalization method to standardize the scale used by the participants. When every participant evaluates the same set of stimuli, the modulus equalization method can be applied. Modulus equalization was the original method to normalize the data (Moskowitz 1978) . Neither modulus normalization nor modulus equalization can guard against the possibility that contextual factors will influence the magnitude of the ratings (Moskowitz 1978) . Additionally, it requires that no participant receive a score of 0 and that each participant assesses the stimuli an equal number of times (Moskowitz 1978). The equation of the modulus equalization method used in individual evaluations is shown in Eq_1.

$$S_{Eq} = S_I \left(\frac{G_{mean}}{S_{mean}}\right) \qquad \text{Eq4}$$

S_{eq} is the equalized score, S_1 is the raw score, G_{mean} is the geometric mean of the scores of all participants on a particular question, and S_{mean} is the geometric mean of the scores of a single participant on all questions.

To determine the interaction between assessments of sound sources, the data gathered in the first and second phases were statistically analyzed using Principal Component Analysis (PCA) with Version 21 of the IBM Statistical Package for Social Sciences (SPSS) software. The experimental data underwent varimax rotation. The Keiser-Meyer-Olkin sampling adequacy measurement (KMO) was used to determine whether the data were sufficiently sampled, and Bartlett's test of sphericity was used to assess whether the data were suitable for size reduction (Field 2005: 647).

4.4 CONCLUSION

This section explained the methods used in the study. First, three different venues were chosen for the first phase of environmental sound recording, and sound sources were collected from selected venues. Then, how web-based listening testing is performed was explained. In addition, the tools used in the sound recording process were also mentioned in this section. Then, the sound design phase, , was explained. Finally, the statistical analysis methods implemented on the data obtained in the sound design experiment were explained.

CHAPTER V

RESULTS

This chapter discusses the positioning of sound sources in recordings of sounds from various environments such as restaurants, open offices, and urban spaces. It also covers how designers create appropriate soundscapes in these environments and apply them to enhance the auditory environment and spatial function, context, and story. In addition, this chapter explains the results of the online web-based listening tests. Furthermore, the results of the second experimental phase, the soundscape design, are discussed.

5.1 FIELD RECORDINGS

This chapter explains that the sound sources in the environmental sound recordings collected from restaurants, open offices, and urban spaces are positioned on the environmental sound design frame model . The list of sound sources identified in the sound recordings collected in restaurants, open offices, and urban spaces are presented in Tables 5, 6, 7 and 8.

Table 5: List of sound sources detected in environmental sound recordings on the restaurant.

Space	Recording Location	Sound Sources
Bigchefs	Interior-1	Music Cutlery Cash Register Unintelligible Speech Intelligible Speech Door Opening/Closing Call Bell Phone Machine Beep Sound
Bigchefs	Interior-2	Music Call Bell Kitchen Serving Car Unintelligible Speech Alarm Door Cash Register
Bigchefs	Interior-3	Music Kitchen Unintelligible Speech Machine Intelligible Speech HVAC Chair/Desk Drag Call Bell Serving Car Cash Register
Bigchefs	Exterior-1	Music Unintelligible Speech Cutlery Wind Chair/Desk Drag Intelligible Speech Phone Automobile

Table 5 Continued

Bigchefs	Exterior-2	Music
		Laughter
		Kitchen
		Unintelligible Speech
		Intelligible Speech
		Chair/Desk Drag
		Announcement
		Wheel Sound
		Wind
		Automobile
		Glass
Bigchefs	Exterior-3	Music
		Cutlery
		Laughter
		Unintelligible Speech
		Child Speech
		Cough
		Phone Application
		Wind
		Bird
		Automobile Horn
		Intelligible Speech
		Phone

Table 6: List of sound sources detected in environmental sound recordings on the restaurant.

Space	Recording Location	Sound Sources
Craft Town	Interior-1	Music Kitchen Unintelligible Speech Intelligible Speech Call Bell Chair/Desk Drag Kitchen Tap Phone Cutlery
Craft Town	Interior-2	Music Unintelligible Speech Intelligible Speech Call Bell Cutlery Chair/Desk Drag Kitchen Tap
Craft Town	Exterior-1	Unintelligible Speech Music Laughter Intelligible Speech Cutlery Wind Phone
Craft Town	Exterior 2	Intelligible Speech Motorcycle Unintelligible Speech Wind Call Bell Automobile Music Cutlery Lighter Phone Cough Laugh Kitchen Call to prayer

Table 7: List of sound sources detected in environmental sound recordings on the open offices.

Space	Recording Location	Sound Sources
Ace Architecture	Interior-1	Mouse Click Unintelligible Speech Pochette Keyboard Cough Cabinet Door Intelligible Speech Laughter Footstep HVAC Kitchen Tap Putting water in glass
Ace Architecture	Interior-2	Mouse Click Footstep Unintelligible Speech Keyboard Light switch Coffee Machine Intelligible Speech Cough Printer Glass Water Machine HVAC Phone Door Opening/Closing

Table 8: List of sound sources observed in sound recordings collected from urban spaces.

Space	Recording Location	Sound Sources
Tunalı Hilmi Kugulu Park	Urban Area-1	Traffic Horn Unintelligible speech Footsteps Motorcycle Car alarm Automobile engine Ambulance siren Intelligible speech Bird Telephone bell Car brake sound
Tunalı Hilmi Kugulu Park	Urban Area-2	Pool/water Swan Unintelligible speech Bird Horn Telephone bell Footsteps Stroller Car brake sound
Tunalı Hilmi Kugulu Park	Urban Area-3	Traffic Horn Car brake sound Wind Unintelligible speech Motorcycle Building site Ambulance siren Car alarm Automobile engine

5.2 RESULTS OF LISTENING TESTS

This section explains the results of the web-based listening tests prepared by the sound recordings collected from restaurants, open offices, and urban areas and performed by the participants.

5.2.1 Restaurants

In restaurants, human movement sound sources are the majority of audible sound sources in the environment. The analysis of the audio recordings reveals that each sound source is consequential. The restaurant's soundscape also included sounds from motor vehicles, social interactions, human voices, instruments, and, lastly, sounds from nature and the sounds associated with (such as rain).

The Kaiser-Meyer-Olkin equation was used to evaluate the analyses, and a KMO value of 0.55 over the acceptable limit of 0.5 served as confirmation. In addition, Bartlett's tests of sphericity revealed that the data were suitable for PCA or factor analysis ($p = 0.00$) (Field 2005: 647). The eigenvalues of each data component were determined using the PCA. The sum of the eigenvalues of the four components is greater than the Kaiser criterion of 1, and the four components together account for %85.3 of the variance. The most significant components, accounting for %41.52 of the variance overall, mainly consisted of sounds heard in dining halls (such as filling a drink, cash register, music, rain, and door). The second component, which accounts for %21.16 of the variance overall, consists of sounds that may call for communication action or attention. The third component, which includes the sounds of cars, motorcycles, and chairs, accounts for %14.92 of the overall variance. The components determined by Principal Component Analysis (PCA), the categorization of sound sources in restaurants, and their locations on the suggested sound design model are presented in Table 10, respectively. Additionally, Table 9 lists all sound sources that can be distinguished in the restaurant sound recordings, along with their corresponding intention and diegesis values.

Table 9: List of sound sources that can be identified in restaurants and their corresponding intent and diegesis values.

Source Type	Sub-category	Sound Sources	Type	Intention Value	Diegesis
Human-made sounds	Motorized transport	Motorcycle	Consequential	-2	1,60
		Automobile	Consequential	-2	4,35
	Human motion	Footstep	Consequential	-1	88,90
		Door	Consequential	-1	38,73
		Stairs Up/Down	Consequential	-1	50,55
		Chair	Consequential	-1	54,04
		Cutlery	Consequential	-1	939,62
		Washing	Consequential	-1	23,09
		Putting water in glass	Consequential	-1	307,30
	Social & communal	Alarm	Intentional	1	18,76
		Phone	Intentional	1	36,65
		Call Bell	Intentional	2	52,01
		Cash Register	Intentional	2	90,82
	Human voice / Instrument	Music	Intentional	3	1990,65
Non-human-made sounds	Nature	Rain	Intentional	-2	1419,13

Table 10: Classification of sound sources in restaurants with the Components defined as a result of the Primary Component Analysis (PCA).

Zone	PCA Components	Sound sources
Creation zone	Component 1: Dining room	Music
Limitation zone	Component 1: Dining room	Cash Register
	Component 2: Attention demanding	Automobile Alarm, Phone
Control zone	Component 1: Dining room	Putting water in glass, Rain, Cutlery
Isolation zone	Component 1: Dining room	Door
	Component 2: Demanding	Stairs Up/Down, Footstep
	Component 3: Disturbing	Motorcycle, Automobile, Chair
	Component 4: Kitchen	Washing

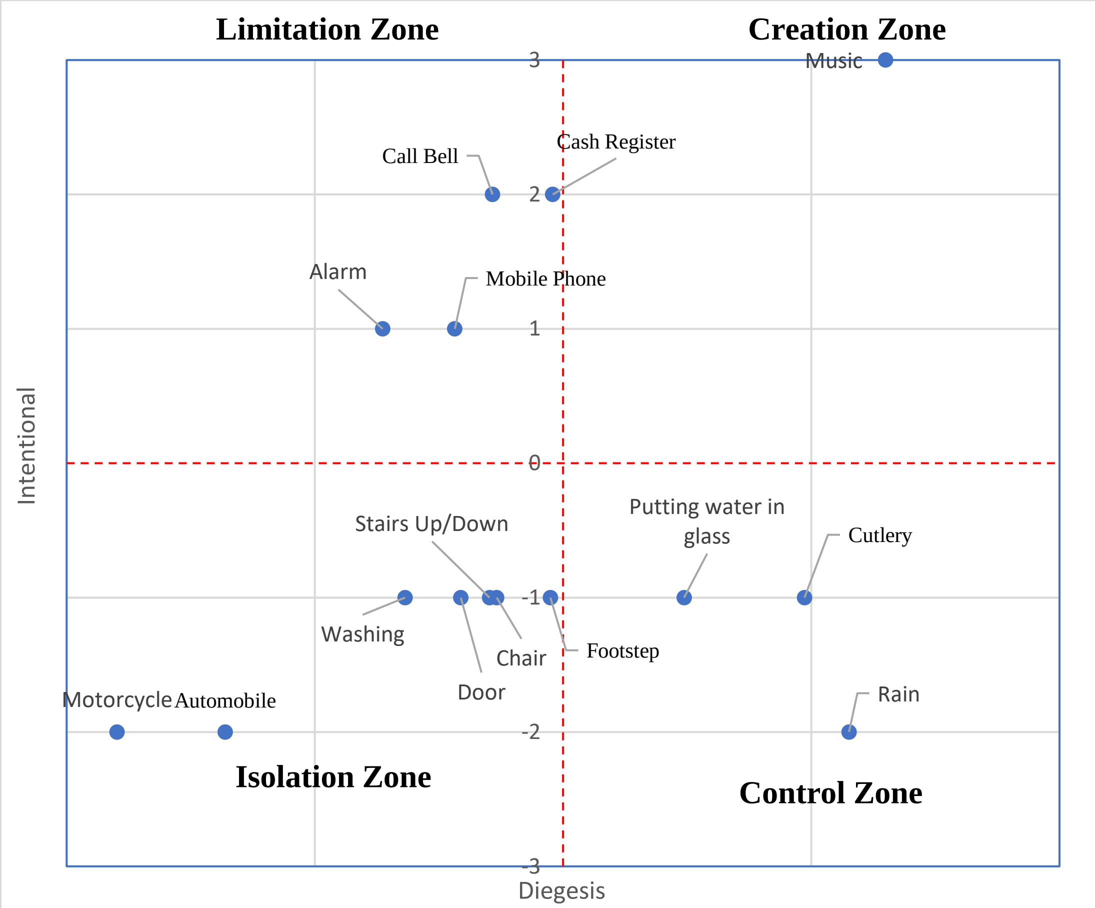

Figure 22: Locations of sound sources in restaurants on the environmental sound design model.

The sound sources were placed on the sound design model based on their diegesis values collected from the listening tests and the intention values defined in the first phase of the study (Figure 22). It has been observed that the isolation zone is where the "disturbing" and "kitchen" components (i.e., the third and fourth components of the PCA) are situated. This shows how distracting traffic, and an open kitchen can be for diners in restaurants. These restaurants should be soundproof to block the incoming traffic noise, by careful space planning, landscaping, and facade design. Additionally, it is crucial to use proper architectural planning to separate the main dining areas from the kitchen and other operational sound sources. The results also showed the importance of music in restaurants. The music sound in the first PCA component is the only sound source positioned in the "creation" zone of the sound design model. The music should be chosen according to the clientele of the restaurants, the atmosphere of the indoor environment, sense of place, and through appropriate planning of the space to create diegesis. Therefore, while designing the soundscape, architects and other environmental designers should advise the music selection.

The "attention demanding" sound sources, which comprise the third PCA component, are located in the "isolation" and " limitation " zones of the sound design model. While digital sound sources in this component, like car alarms and mobile phones ringing, are located in the limitation zone of the model, human movement-related sound sources, like walking upstairs and footsteps, are located in the isolation zone of the model. This finding indicates that consumers do not want to be excluded from information-conveying sound sources. It was observed that these sound sources are not preferred to dominate the restaurant's soundscape. This result reveals that restaurant users do not want to be separated from information-bearing sound sources. However, it is not preferred that they emerge as a dominant element in the restaurant's indoor soundscape. The first PCA component, "dining area," seems to be dispersed throughout all four zones of the sound design model. Particularly in restaurants, cutlery and pouring drink noises from patrons should be kept to a minimum. This result indicates that customers desire to hear these sound sources in restaurants, but the designer must ensure they are contextually appropriate, designers add. Similarly, customers like hearing the cash register sound in the restaurant's indoor soundscape but dislike it when they dominate it.

5.2.2 Open-plan Offices

The majority of the sound sources found in an open-plan office were human movement sounds. The sound sources identified in the open-plan office audio recordings were consequential. Table 11 lists each sound source identified in the open-plan office audio recordings ,along with the corresponding intention and diegesis values. The open-plan office soundscape included human movement sounds, electro-mechanical sounds, social and societal sounds, and finally, animal sounds.

Table 11: List of sound sources that can be identified in open-offices and their corresponding intent and diegesis values.

Source Type	Sub-category	Sound Sources	Type	Intention Value	Diegesis
Human-made sounds	Human motion	Cabinet	Consequential	-1	19,00
		Door	Consequential	-1	109,59
		Mouse Click	Consequential	-1	73,38
		Light switch	Consequential	-1	92,12
		Keyboard	Consequential	-1	126,96
		Water Tap	Consequential	-2	32,37
		Papers	Consequential	-1	52,36
		Pencil	Consequential	-1	167,39
		Footstep	Consequential	-1	110,68
	Electromechanical	Coffee Machine	Intentional	2	72,08
		Printer	Intentional	1	75,11
		HVAC	Consequential	-2	18,99
		Copying machine	Intentional	1	54,02
	Social & communal	Office Phone	Intentional	2	21,43
Non-human-made sounds	Animals	Cat	Consequential	-2	41,08

Listening test analysis of the open office environment was evaluated using the Kaiser-Meyer-Olkin scale. The KMO value above the acceptable limit of 0.5 was confirmed as 0.72. In addition, Bartlett's tests of sphericity revealed that the data were suitable for the PCA or factor analysis ($p = 0.00$) (Field 2005: 647). The eigenvalues of each data component were determined using the PCA. The sum of the eigenvalues of the four components is greater than the Kaiser criterion of 1, and the four components together account for %94.01 of the variance. The most significant components, accounting for %52.36 of the variance overall, mainly consisted of sounds heard in an open-plan office environment (such as light switch, keyboard, pencil, printer, HVAC, and office phone). The second component, which explains %24.55 of the total variance, consists of sounds rarely heard in open-plan offices due to low sound intensities or low frequency of use (such as mouse click, door, and copy machine). Kitchen cabinet and coffee machine sounds are in the third component, explaining %9.71 of the total variance. The fourth component, which includes paper and document sounds, explains %7.39 of the total variance. After the analysis of the four components, Component 1 was defined as "open-plan office environment (frequently heard)'', Component 2, "open-office environment (rarely heard)'', Component 3, "break time," and finally, Component 4 "papers." The definitions of these four components are presented in Table 12.

Table 12: Classification of sound sources in open offices with the Components identified as a result of the Primary Component Analysis (PCA).

Zone	**PCA Components**	**Sound Sources**
Creation zone	No components	No sound source
Limitation zone	Component 1: Open office (frequently heard)	Printer, Office Phone
	Component 2: Open office (rarely heard)	Copying machine
	Component 3: Break time	Coffee Machine
Control zone	Component 1: Open office (frequently heard)	Keyboard, Pencil, Footstep
	Component 2: Open office (rarely heard)	Door
Isolation zone	Component 1: Open office (frequently heard)	Light switch, Cat, Water tap, HVAC
	Component 2: Open office (rarely heard)	Mouse Click
	Component 3: Break time	Cabinet
	Component 4: Papers	Papers

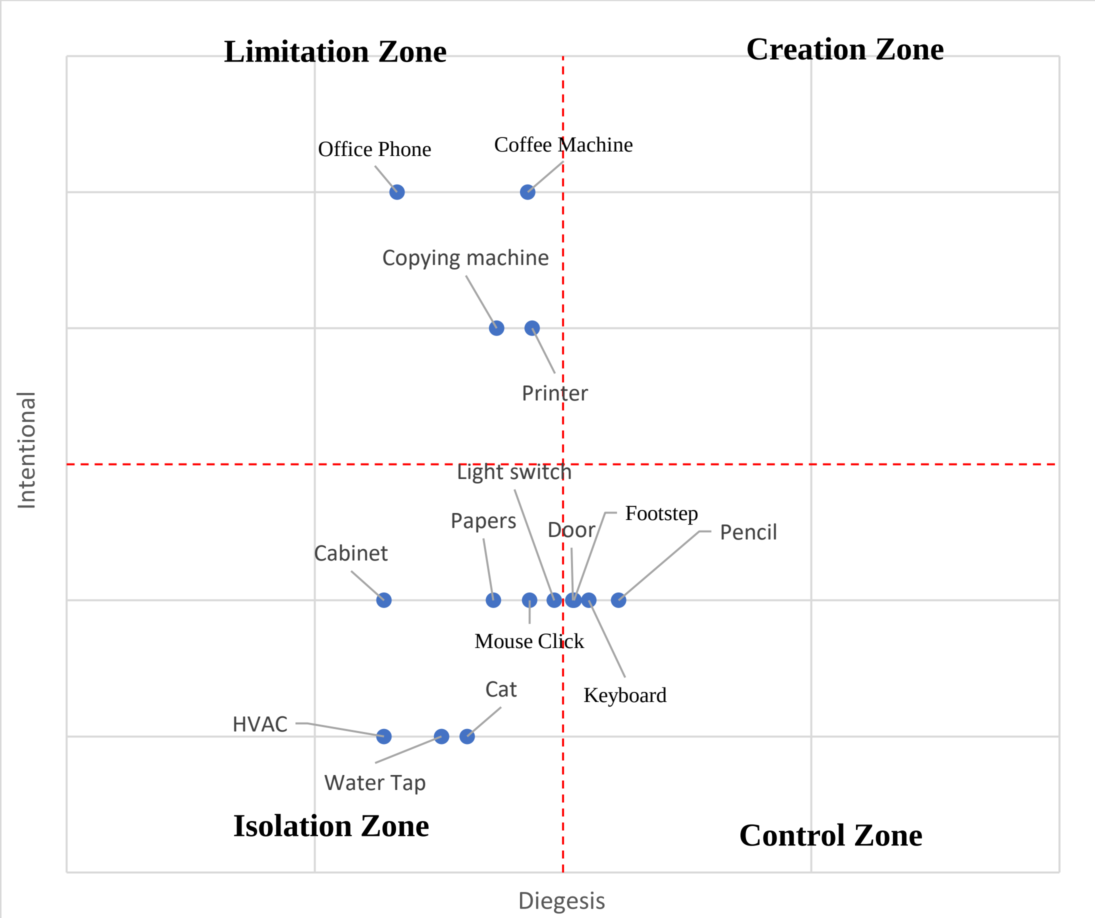

Figure 23: Locations of sound sources in the open-plan offices area on the environmental sound design model.

The sound sources were positioned on the sound design model according to the intention and diegesis values , (Figure 23). It is observed that there is absence of sound sources in the creation zone. When the results are examined, it is seen that deliberate sound sources such as office phones, copiers, coffee machines, and printers do not have high diegesis values, and they are intentional sounds. In contrast, sounds with high diegesis values, such as door, footsteps, pencil, and keyboard, are consequential sounds. Designers should avoid choosing noisy environments, such as open-plan offices, and isolate all distracting sound sources. Furthermore, although electromechanical and social/societal sounds with distracting properties and distributed in the first, second, and third components of PCA and located within the limitation zone of the environmental sound design model cannot be completely isolated due to their compatibility with the context of open-plan offices, they can be controlled with appropriate architectural planning. The environmental sound design model's control zone contains computer keyboard, pencil, foot, and door sounds. It can be seen that the isolation zone of the sound design model includes the sound sources from each of the four PCA components. Since they have the lowest diegesis values of all the sound sources in this space, the designer must isolate sound sources such as HVAC, kitchen cabinets, running water from a faucet, and animal sounds. The presence of such sound sources in open-plan office areas is not expected and preferred by users. Other sound sources (light switch, papers, and mouse click) is in the isolation zone; since these sounds are common in the outside world and have higher diegesis values, the designer must take extra care to isolate them.

5.2.3 Urban Areas

The analysis of the audio recordings of the urban area shows that the majority of the sound sources that can be identified are emitted by motorized vehicles. Two of the five distinct sound sources from motorized vehicles were intentional. The urban area have a variety of sound sources in addition to motorized vehicles, including human-motion, electro-mechanical, social, natural, and animal sounds.

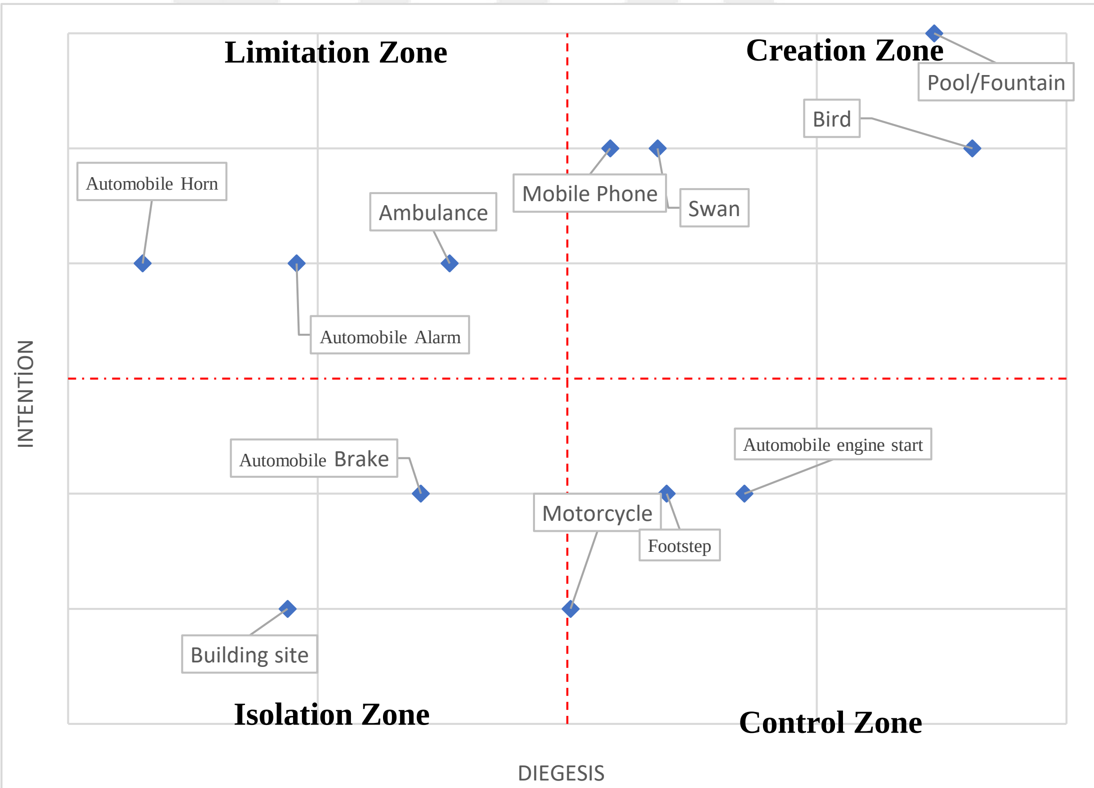

Figure 24: Locations of sound sources in urban areas on the environmental sound design model.

Table 13: List of sound sources that can be identified in urban spaces and their corresponding purpose and narrative values.

Source type	Sub-category	Sound Sources	Type	Intention	Diegesis
Sounds generated by human activity/facility	Motorized transport	Motorcycle	Consequential	-2	103.11
		Automobile brake	Consequential	-1	25.91
		Automobile horn	Intentional	+1	1.99
		Automobile engine	Consequential	-1	512.20
		Ambulance	Intentional	+1	33.78
	Human motion	Footsteps	Consequential	-1	250.31
	Electromechanical	Construction	Consequential	-2	7.57
		Mobile phone	Intentional	+2	148.54
	Social & communal	Automobile alarm	Intentional	+1	8.23
Sounds not generated by human activity	Nature	Fountain	Intentional	+3	2949.44
	Animals	Birds	Intentional	+2	4202.18
		Swan	Intentional	+2	229.91

The listening test analyzes of the urban area were evaluated using the Kaiser-Meyer-Olkin scale. The KMO value above the acceptable limit of 0.5 was confirmed as 0.67. Bartlett's tests of sphericity revealed that the data were suitable for the PCA or factor analysis (p = 0.00)(Field 2005: 647). The eigenvalues of each data component were determined using the PCA. The sum of the eigenvalues of the four components is greater than the Kaiser criterion of 1, and the four components together account for %72.7 of the variance. The components, accounting for %34.5 of the overall variance, mainly consisted of sounds expected to be heard in an urban area (such as alarming sounds, car brakes, and car horns). Birds, footsteps, and water fountains make up the second component, which accounts for %15 of the total variance. The third component, which includes the sounds of motorized vehicles, accounts for %12.99 of the total variance. The fourth component, which explains %9.35 of the total variance, includes mobile phone sounds. After analyzing the four components, Component 1 was defined as "stimulus sounds"; Component 2, as "natural sounds"; component 3, as "mechanical sounds," and finally, Component 4, as "digital sounds". The definitions of these four components are presented in Table 14.

Table 14: The sound sources categorized depending on the extracted components from the Principal Component Analysis (PCA).

Creation zone	Component 2: Natural sounds	Pool/fountain and birds
	Component 4: Digital sounds	Cell phone
Limitation zone	Component 1: Alarming sounds	Car horn, car alarm, and ambulance
Control zone	Component 3: Mechanical sounds	Motorcycle and car engine
	Component 2: Natural and human sounds	Footsteps
Isolation zone	Component 1: Alarming sounds	Car brake and construction

Natural and human sounds, the second PCA component, and sound sources are all highly anticipated in the sound design model's creation zone. Users in the area anticipate hearing sound sources associated with digital sounds, which is the fourth component of the PCA, resulting from the sound sources in the creation zone. The stimulus sounds, the sound sources in Component 2, can be controlled by urban planning to limit the excessive environmental noise. The designer should also consider the third PCA component (mechanical sounds). These sound sources are positioned in the isolation zone of the sound design model. Car braking and construction noises might be completely isolated by the designers. Users expect to hear motorcycle and car engines in the control area. Control of these noises and planning should be used. It is not advisable to completely isolate these sounds because doing so will reduce the environment's sense of place.

5.3 SOUND DESIGN EXPERIMENT

In the second phase of the study, sound design processes were carried out for three different venues. The sound sources, sound levels of the audio channels, and the reverberation times determined by the participants were collected as the data set. The statistical analysis method was presented in Section 4.3.2.

5.3.1 Restaurants

The sound sources determined by the participants are shown in Figure 25. The average sound levels (dB) for these sound sources is presented in Figure 26. In the sound level graph in Figure 26, 0 dB indicates the highest sound level, and -25 dB indicates the lowest sound level. Audio channels other than the first and second do not carry spatial information; however, since the frequency spectrum differs, it was thought that whether the designers agreed or not was more important than which sound source they chose. A paired samples T-test with a two-tailed distribution was used to analyze the variance in the participants' choices for sound sources in the restaurant setting. The T-test results showed that there was no significant difference between the sound source preferences for Channel-1 (background sound), Channel-2 (footstep), Channel-6 (service bell), and Channel-8 (cash register). Other sound sources showed no significant difference. First, %62.5 of participants contextual appropriateness the "dining hall" recording, %33.75 the "outdoor" sound recording, and %3.75 the participant's "kitchen" recording as background noise, considering their preferences for sound sources with different semantic connotations and spatial connotations. When the preferences for the footsteps in the second sound channel are looked at, it can be seen that %53.75 of the designers prefer footsteps that happen on concrete floors, %36.25 prefer footsteps that happen on parquet floors, and %10 prefer footsteps that happen on carpet floors.

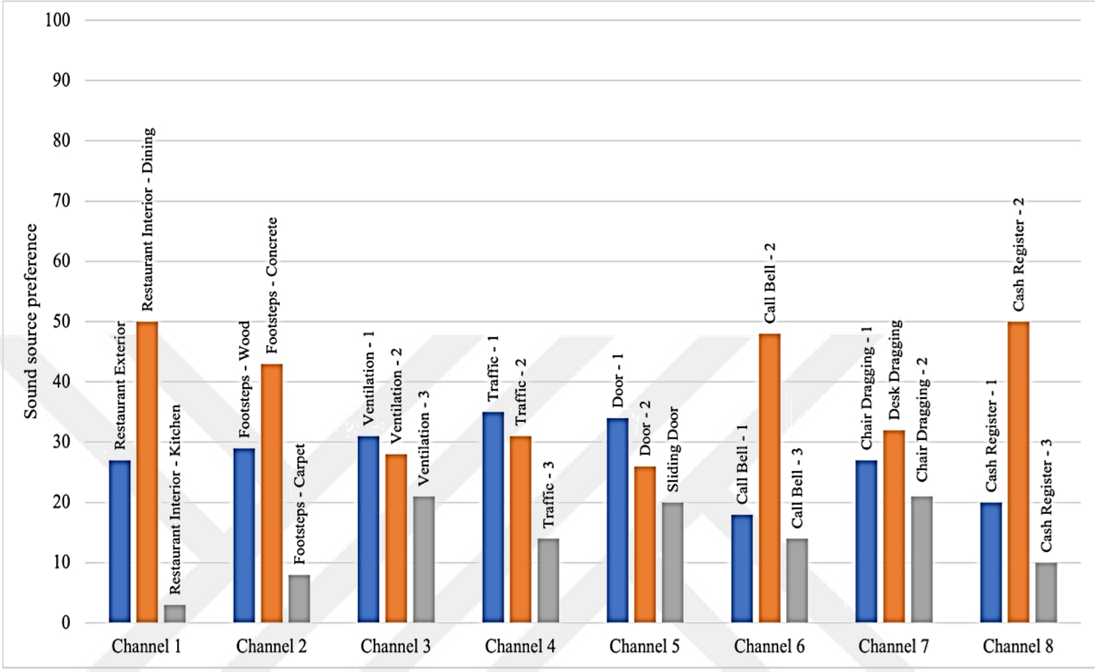

Figure 25: The number of designers who prefer the sources preferred by designers for each sound channel in restaurant soundscape design.

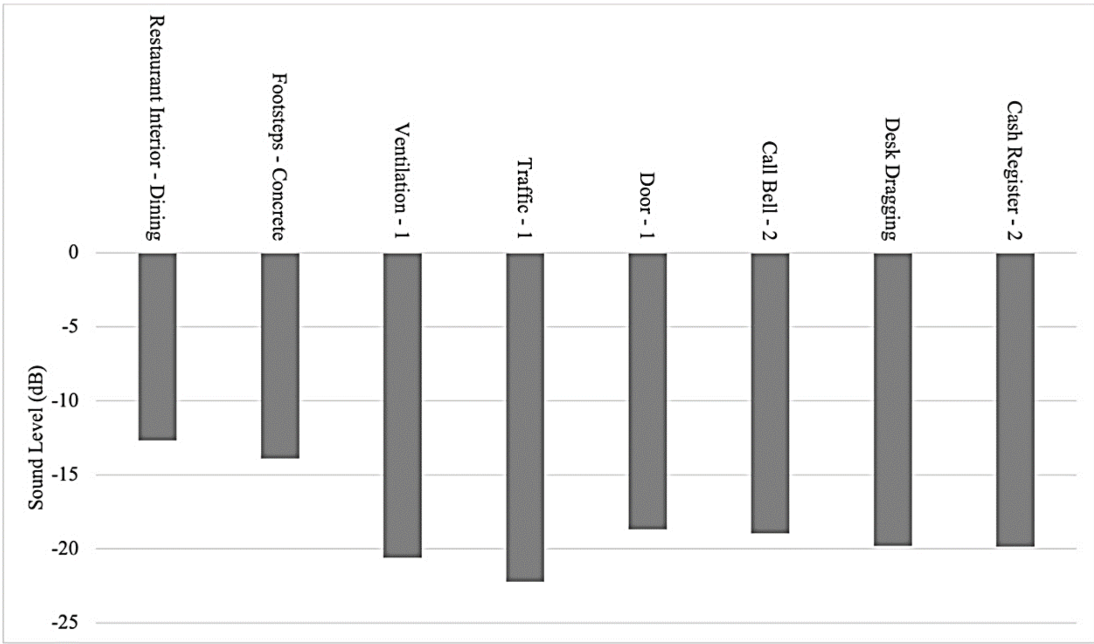

Figure 26: Average sound levels of sound sources preferred by designers in restaurant soundscape design.

The relationship between preferred sound sources was tested statistically by Principal Component Analysis. Sample adequacy of the restaurant environment analysis was evaluated using the Kaiser-Meyer-Olkin scale. The KMO value above the acceptable limit of 0.5 was confirmed as 0.72. In addition, Bartlett's tests of sphericity revealed that the data were suitable for PCA or factor analysis (Field 2005: 647). The two components account for %61.6 of the variance, and the sum of their eigenvalues exceeds the Kaiser criterion of 1. The product and traffic sounds (such as ventilation, traffic, doors, service bells, chair/table drag, and cash register) made up most of the most significant components, accounting for %46.60 of the total variance. It has been noted that sound sources with high spatial information make up the second component, which accounts for %15 of the total variance (background sound and footstep sound). Component 1 was identified as "containing spatial information," Component 2, and "non-spatial information" after the two components were analyzed. The PCA results show that the contextual appropriateness of sound levels for the preferred sound sources in restaurant design are higher for the sound sources carrying spatial information than for those not carrying spatial information.

5.3.2 Open-plan Offices

The sound sources preferred by the participants in the sound design process for the open office interiors are shown in Figure 27. The sound level (dB) they consider appropriate for these sound sources is shown in Figure 28. A paired T-test with a two-tailed distribution was used to analyze the variations in the participants' preferences for sound sources in the open office setting. The T-test results applied to the data indicate a semantic difference in the preferred sound sources across all of the employed sound channels ($p = 0.00$). First, 50% of the participants in the background sound recording "office indoor 1," 35% of the participants in the sound recording "office indoor 2," and "office indoor 3" were chosen to represent their preferences for sound sources with semantic differences and space information. It was observed that %15 of the participants preferred a 3' sound recording. According to preferences for the footsteps in the second sound channel, it was discovered that %45 of the designers preferred carpet flooring, %45 preferred concrete flooring, and %10 preferred footsteps that occur on parquet floors. The participants' calculated average reverberation times are 0.31 seconds.

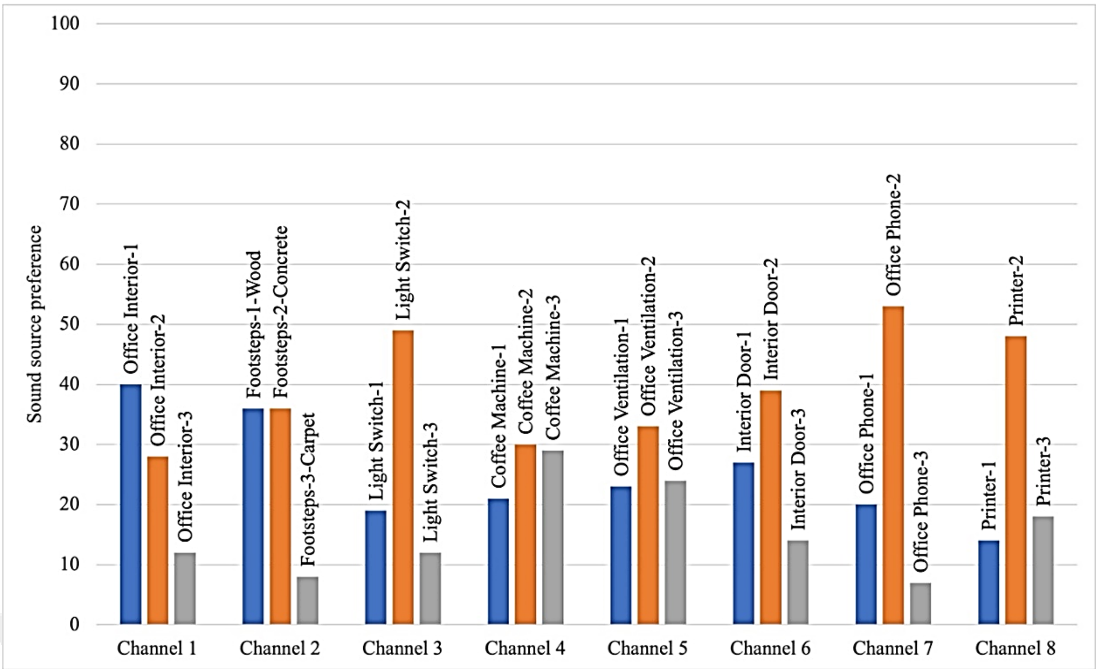

Figure 27: The number of designers who prefer the sources preferred by designers for each sound channel in open offices soundscape design.

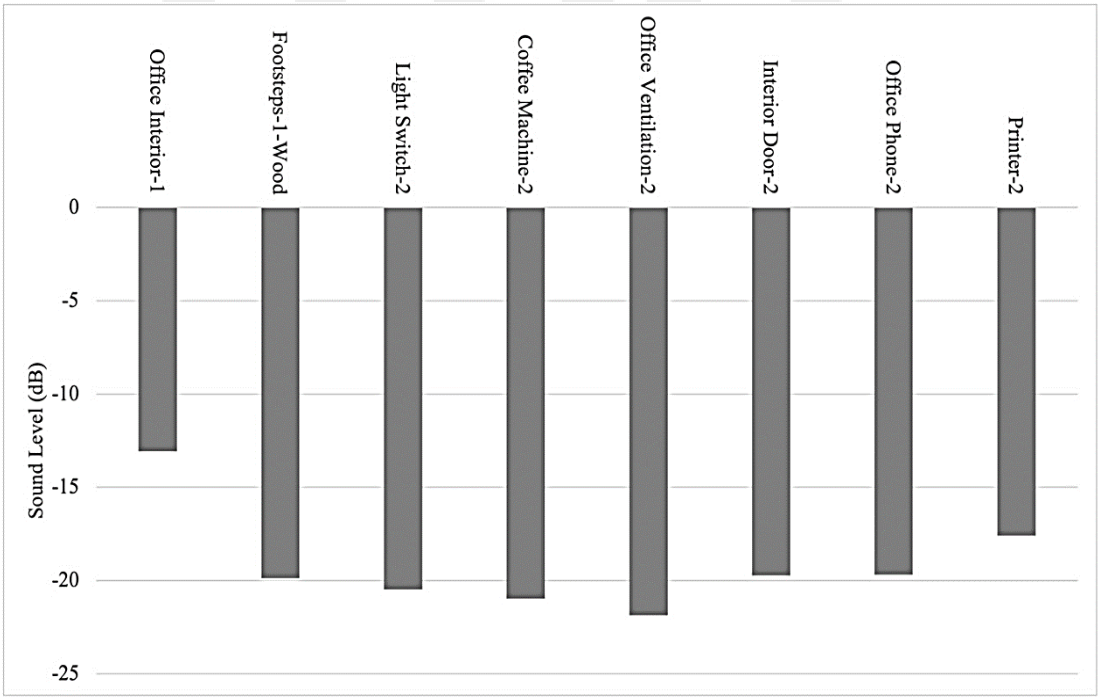

Figure 28: Average sound levels of sound sources preferred by designers in open offices soundscape design.

The relationship between preferred sound sources was tested statistically by Principal Component Analysis. Sample adequacy of the open offices' environment analysis was evaluated using the Kaiser-Meyer-Olkin scale. The KMO value above the acceptable limit of 0.5 was confirmed as 0.82. In addition, Bartlett's sphericity tests revealed that the data were suitable for PCA or factor analysis (Field 2005: 647). The two components together account for %63.02, and the sum of their eigenvalues exceeds the Kaiser criterion of 1. Steps, a light switch, a coffee maker, ventilation, and door open/close were the main contributors, accounting for %48.81 of the total variance. It has been noted that sound sources with background sound recordings, computer printers, and office phone sounds make up the second component, which accounts for %14.21 of the total variance. The primary distinction between the two components is that while Component 2's sounds are specifically related to the work, Component 1's sounds are related to the space's overall functionality. Component 1 was identified as "non-work-related sounds," Component 2, and "work-related sounds" after analyzing the two components. According to the PCA results, which show the sound levels of the preferred sound sources, designers of open offices prefer sound levels of sound sources related to works higher than sound levels of sound sources unrelated to works.

5.3.3 Urban Areas

The sound sources preferred by the participants in the sound design process for the urban areas are shown in Figure 29. The sound level (dB) they consider appropriate for these sound sources is shown in Figure 30. A paired T-test with a two-tailed distribution was used to statistically analyze the participants' differing sound source preferences in an urban setting. According to the T-test results applied to the data, there is a semantic difference between the sound source preferences in all the sound channels used (p = 0.00). When the preferences of sound sources that have semantic differences and carry spatial information are examined, %53.75 of the participants in the 'urban space - fountain sound' recording, %25 of the 'urban area - park' sound recording, and 'urban space - traffic' as the background sound. It is observed that sound recording is preferred by %21.25 of the participants. When the preferences on the footsteps in the second sound channel are examined, it is observed that %55 of the designers prefer the footsteps that occur on the gravel floor, %25 on the concrete floor, and lastly %20 on the wooden floor. The average of the reverberation times determined by the participants is 0.35 seconds.

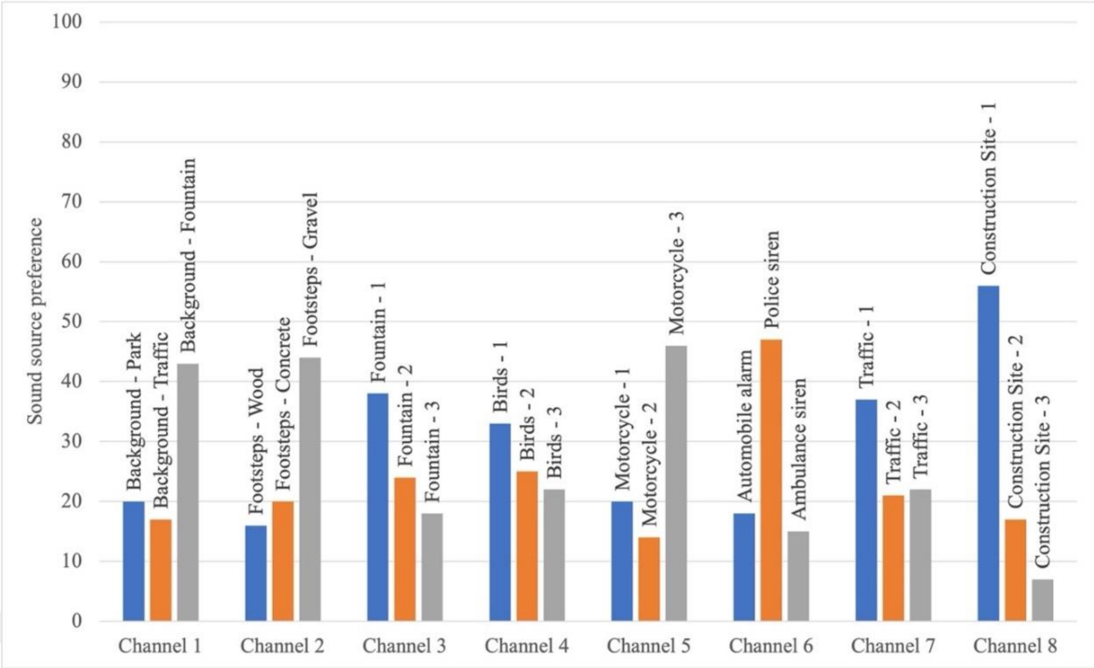

Figure 29: Average sound levels of sound sources preferred by designers in urban area soundscape design.

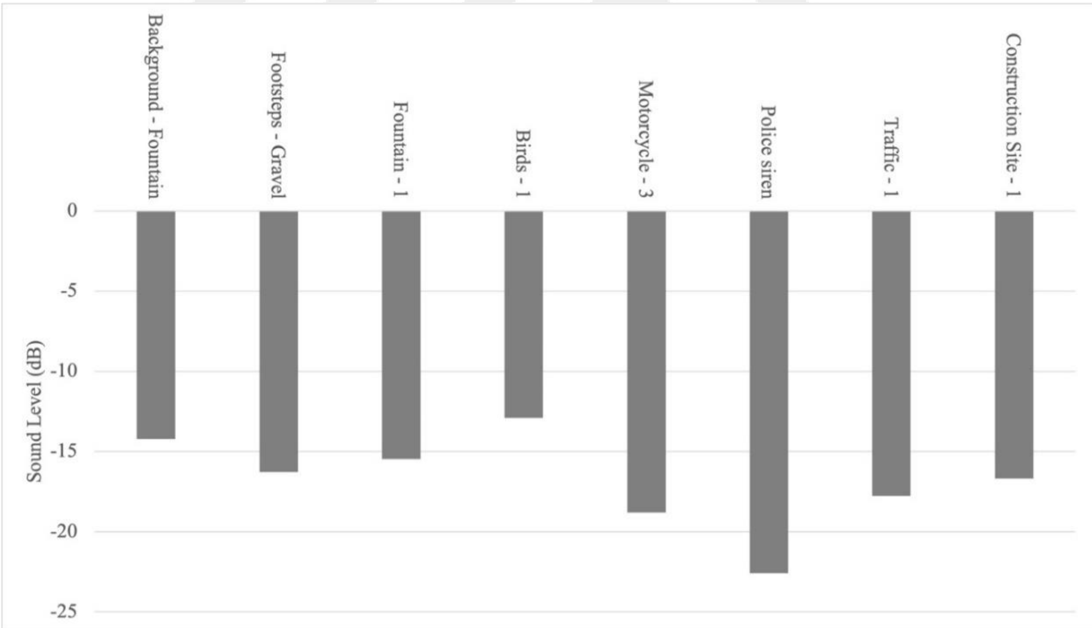

Figure 30: The number of designers who prefer the sources preferred by designers for each sound channel in urban area soundscape design.

CHAPTER VI

DISCUSSION

This chapter discusses the two experimental phases of the study: (1) Collecting sound recordings from selected venues and Web-based listening tests, (2) Sound design experiment.

This thesis aimed to implement the sound design methods of films and industrial design in architecture. This thesis also applied film sound design, diegesis, and sound source identification theories. These study hypotheses demonstrated how the ambient context in indoor soundscapes was discussed. Based on the findings of the initial web-based listening tests conducted in restaurants, this study reveals that the "disturbing" and "kitchen" components have emerged as the primary concerns in restaurant environments. This suggests that restaurant users experience discomfort from open kitchens and traffic noise. Additionally, the results of the second phase of the study's sound design experiment further confirm this observation. The "outdoor" sound recording was preferred by %33.75 of the participants, while only %3.75 preferred the "kitchen" sound recording. Therefore, designers proposing sound designs for restaurants should first isolate traffic noise using appropriate spatial planning, landscaping, and building acoustic techniques. The frequent use of open kitchens in restaurants in recent years has had a negative impact on the indoor soundscape. The study also highlights the importance of music in restaurants, as demonstrated by the fact that %62.5 of the participants preferred the "dining room" recording as background noise. The selection of the appropriate music range should consider the user profile of the restaurant, the kitchen and menu, the indoor atmosphere and sense of place, the creation of diegesis, and the correct storytelling of the space. The results also indicate that "attention-demanding" sound sources should be isolated and limited in the environmental sound design model.

Digital sound sources in this component should be limited, while human movement sound sources should be isolated. This finding suggests that restaurant users want to avoid information-carrying sound sources, while sounds related to human movement are not preferred. The study further reveals that the participants' preferences for footstep sounds depend on the type of flooring material used, with %53.75 preferring footstep sounds on concrete flooring, %36.25 preferring footstep sounds on parquet flooring, and only %10 preferring footstep sounds on carpeting. Hence, sound designers should select suitable flooring materials to isolate these sound sources. Finally, the study emphasizes the need to control sound sources produced by restaurant users during the eating/drinking function, such as fork/knife and glass sounds. Although users expect to hear these sounds in restaurants, sound designers must control them.

The first notable result in the analysis of sound sources in the soundscape of the open-office indoor environment based on listening tests was that no sound source was present in the model's creation zone. Open offices are created in spaces requiring high attention and are risky in architectural acoustics. Therefore, the fact that users do not prefer dominant sound sources highlights the necessity of isolating all distracting sound sources. When the results were examined, it was determined that intentional sound sources such as office phones, copy machines coffee machines, and printers did not have high diegesis values. In contrast, sounds with high diegesis values, such as doors, footsteps, pencils, and keyboards, were identified. As a result of the sound design experiment, spatial and semantic differences were observed among all sound sources. These results are consistent with the sound design study, in which the "office interior 1" recording was preferred by %50 of participants as background noise, the "office interior 2" recording was preferred by %35 of participants, and "office interior 3" recording was preferred by %15 of participants. In addition, electromechanical and social/communal sounds with distracting qualities cannot be completely isolated due to their compatibility with the context of open offices. However, they must be controlled through appropriate architectural planning. When the user preferences for footsteps in the second audio channel were examined in the sound design experiments, it was observed that %45 of users preferred footsteps on parquet flooring, %45 on concrete flooring, and %10 on carpet flooring. Footsteps that have high diegesis values and are present in the soundscape of the open-office indoor environment can be controlled by architectural design decisions, such as carefully choosing floor finishes, by the sound designer. Finally, according to the listening test results, it was observed that HVAC systems, kitchen cabinets, water taps, and animal sounds with the lowest diegesis values must be completely isolated by the designer. Users do not expect or prefer these types of sound sources to be present in open-office workspaces.

According to the results of listening tests, it has been revealed that sound sources associated with natural sounds, such as bird, swan, and water sounds, are highly expected in the creation zone of the sound design model in an urban area. The results of the sound design experiment also support this information. According to the results of the sound design phase, participants' preferences for sound sources were primarily observed to be the "urban space-fountain" recording, selected by %53.75 of participants as background noise, followed by the "urban space-park" sound recording preferred by %25 of participants and the "urban space-traffic" sound recording preferred by %21.25 of participants. An environmental sound designer should create an appropriate environment that mimics the natural environment, which hosts animal life to increase the healing properties of the area. Another exciting result revealed by the sound design model regarding the sound sources in the creation zone is that users in urban environments preferred sound sources associated with digital sounds. Based on this result, it is concluded that even in urban and healing spaces, users do not prefer to be completely isolated from social communities and modern lifestyles. Therefore, it is necessary to carefully balance modern lifestyles and healing properties in the design process. During the sound design study, when the preferences for footsteps on the second sound channel were examined, it was observed that %55 of designers preferred footsteps on pebble ground, %25 on concrete flooring, and %20 on wooden flooring. The sound designer should also consider controlling human-generated footsteps.

CHAPTER VII

CONCLUSIONS

In this chapter, firstly, the main findings obtained in the thesis are explained. After that, a summary of each chapter is given, and the impacts of the research are mentioned. Lastly, the suggestions for future works and the limitations of the thesis study are explained.

7.1 FINDINGS

The primary aim of the thesis is to offer a new proposal on the sound source classification methods previously proposed in the literature within the context of sound design analysis and synthesis methods, which play an essential role in the built environment of sound elements for films and video games. This model will assist designers and architects in classifying sound sources as design elements of the built environment by the functions of the spaces. For the sound design model, experimental studies were carried out over two phases in three spaces with varying functions: a restaurant, an open office, and an urban area. After this, the two phases of the experimental study involved gathering and examining environmental sound recordings, conducting web-based listening tests, and designing the soundscape.

Main findings of the thesis:

- Depending on the purpose of a given space, variations in sound sources and the types of sounds that occur in different areas are anticipated.
- The proposed environmental sound design model can guide architects and other environmental designers in designing soundscapes.
- The proposed environmental sound design model enables monitoring of how each sound source should be regulated and placed in accordance with the purposes, contexts, and stories of the places.

- Sound sources positioned in the four zones of the presented sound design model guides indoor and urban soundscape designers by defining the degree of designability.
- When assessing the same sound source for spaces with varying functions, its placement in the model will shift based on the context of the spaces and the progression of the story in the diegesis axis. As a result, the suggested sound design model differs from other classification approaches found in the literature.
- The findings indicated that environmental sound designers can consider the contextual appropriateness of participants, including the specific setting and intended use of the sound events, to inform their design process.
- It was discovered that the sound designer should handle the sound sources in the indoor soundscape according to the context of each space using various techniques.
- Sound design must be customized for the users involved, and it should convey specific emotions and meanings. Every visual and auditory component of the built environment must be intentionally and thoughtfully planned by the designer.

7.2 SUMMARY OF THE CHAPTERS

The chapters of the thesis are summarized in this section. Chapter 2 describes the relevant topics from the literature discussed and supported by previous research to help the studies envisioned realize this thesis. First, properties of sound and definitions of architectural acoustics were discussed. The method for indoor and urban soundscapes is then described. Later, one of the main goals of this thesis to describe the concept of sound design in film theory and product design was explained. Finally, the sound classification techniques in the literature were examined and explained using evidence from earlier research published in the literature.

Chapter 3 outlines the proposed model for environmental sound design. This model aims to provide guidance to architects and other environmental designers during the design process by specifying the degree and type of control they can exert over sound sources based on the type of sound source and contextual requirements of the space.

The methods used in the two phases of the study are described in Chapter 4. First, sound sources were collected from the three venues chosen and explained. The process for conducting web-based listening testing is then described. This section also includes information on the equipment used to collect environmental sounds. The second phase of the thesis, the sound design experiment, is then explained using the instruments employed. The statistical methodology used for the data gathered during the sound design experiment is finally explained in this chapter.

Chapter 5 presents the results of the study. The proposed sound design model was tested in three venues: a restaurant, an open office, and an urban area. Additionally, as a component of the environmental sound design model, the placement of the sound sources in the environmental sound recordings from restaurants, open offices, and urban areas, the creation of the proper diegesis situation in these spaces under the zone where they are located, and their application by the designer to make the auditory environment and spatial function, context, and story consistent are all described in this chapter. Also, chapter 5 explains the sound design process, results, and statistical data, which is the second phase of this thesis. In this process, the purpose of the sound design model was to apply various methods to control the sound source in a built environment. The sound design processes with the sound design model have been experimented with in three venues: a restaurant, an open office, and an urban area.

7.3 IMPACT OF THE RESEARCH

This section discusses the impact of the research. Firstly, the proposed environmental sound design model will provide a different perspective on a holistic sound design approach that goes against the predominance of visual aesthetics in design disciplines such as architecture, interior design, urban and regional planning, which are often overlooked in favor of the visual aspect. Secondly, by leaving the control of audio-visual tests to designers, the impact of design decisions on the overall environmental experience will be observed. Thirdly, when combined with existing studies on architectural acoustics, sound environment, and audio-visual interactions, the results will help create a fundamental guide for the design process of sound environments. Finally, a comprehensive and high-quality environmental sound sample library will be created for future studies.

7.4 SUGGESTIONS FOR FUTURE RESEARCH AND LIMITATIONS

This section describes suggestions for future research and the limitations of the study. The suggestions for future research are :

- Sound sources located in the presented model's limitation, isolation, creation, or control zones can positively contribute to indoor and urban soundscape designs when designed using the methods specified in the guide.
- The proposed and developed sound design model was used in only three different venues (restaurant, open office plan, and urban area) within the scope of this thesis. It can also be used in places with many kinds of sound sources in future studies (e.g., schools, religious buildings, shopping malls, residences, and hospitals).
- Integrating the sound design model developed with the data collected from all these studies into architecture and interior architecture education.

The limitations of the research are:

- Firstly, the current limitation of the present study is the intention values were decided subjectively. Therefore, it is suggested that future studies conduct experimental research and collect empirical evidence to identify the diegesis values for environmentally sound sources.
- The web-based listening tests as part of this thesis were conducted online due to the COVID-19 pandemic, which was influential globally during the thesis. In the second phase of the thesis, in the sound design experiment, possible analysis deviations were prevented by performing the listening tests face-to-face and with standard technical equipment. Furthermore, in the sound design experiment, the spaces were designed using the sound design model and were evaluated by the users.

This thesis work is also part of the scientific research project numbered MF.20.002, which is supported by the Scientific Research Projects unit of Cankaya University. The environmental sound recording phase, which was planned to be realized for the scientific research project and the thesis work, was delayed for a short time from the planned date due to the delay in the procurement process of the sound recording equipment.

The data obtained from the thesis study's restaurants and open offices stages were presented at the Inter-Noise 2021 international congress held in Washington (USA) and published in the proceedings book (Kitapci and Ozdemir 2021a). In addition, the data obtained from the works of the project for urban spaces were presented at the Euronoise-2021 international congress held in Portugal on 25-27 October 2021 and published in the proceedings book (Kitapci and Ozdemir 2021b).

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