

INVESTIGATING THE EFFECT OF INDOOR SOUNDSCAPING TOWARDS  
EMPLOYEES' MOOD AND PERCEPTION IN OPEN PLAN OFFICES

A Master's Thesis

by

Volkan Acun

Department of  
Interior Architecture and Environmental Design  
İhsan Doğramacı Bilkent University  
Ankara  
August 2015

INVESTIGATING THE EFFECT OF INDOOR SOUNDSCAPING TOWARDS  
EMPLOYEES' MOOD AND PERCEPTION IN OPEN PLAN OFFICES

Graduate School of Economics and Social Sciences  
of  
İhsan Doğramacı Bilkent University

By

Volkan Acun

In Partial Fulfilment of the Requirements for the Degree of  
MASTER OF FINE ARTS

in

DEPARTMENT OF  
INTERIOR ARCHITECTURE AND ENVIRONMENTAL DESIGN  
İHSAN DOĞRAMACI BİLKENT UNIVERSITY  
ANKARA

August, 2015



I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Fine Arts in Interior Architecture and Environmental Design.

---

(Assoc. Prof. Semiha Yilmazer)  
Supervisor

I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Fine Arts in Interior Architecture and Environmental Design.

---

(Assist. Prof. Yasemin Afacan)  
Examining Committee Member

I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Fine Arts in Interior Architecture and Environmental Design.

---

(Assoc. Prof. Arzu Gnen Sorgu)  
Examining Committee Member

Approval of the Graduate School of Economics and Social Sciences

---

(Prof. Erdal Erel)  
Director

## **ABSTRACT**

### **INVESTIGATING THE EFFECT OF INDOOR SOUNDSCAPING TOWARDS EMPLOYEES' MOOD AND PERCEPTION IN OPEN PLAN OFFICES**

Volkan Acun  
MFA., Interior Architecture and Environmental Design  
Supervisor: Assoc. Prof. Semiha Yilmazer

August, 2015

Over the past decade, soundscape studies have proposed ways to differentiate sonic environments and showed that it is not always the sound levels that matters. Meanings associated with sound sources, how they are perceived by the listener and the physical settings are equally important. On the other hand, very few studies are conducted to examine whether these principles of soundscape can be applied to indoor spaces. Aim of this research is to identify sound sources within an open office space, understand how employees' perceive these sound sources, explore its impact on their mood and task performance. In order to achieve this goal, measurements and interviews are conducted at two different open planed offices. A user focused, subjective, approach of Grounded Theory, is used to capture the lived experience of an open plan office space and examine the effects of indoor soundscape quality towards employees' perception of their work environment.

PANAS (Positive and Negative Affect Schedule) test is conducted to explore employees' mood. In order to understand the acoustical conditions of case study settings, in-situ measurements of sound levels (Leq), ODEON simulation of Speech Transmission Index (STI) and Reverberation Time (T 30) is used. Semi-structured interviews, as part of Grounded Theory, and PANAS test are conducted with 47 employees. Their responses are used to generate a conceptual framework which conceptualizes employees' subjective response to the soundscape of their work environment. Generated conceptual framework showed patterns between employees' perception of sound sources, sound preference and type of work they are performing as well as the association between positive affect (PA), negative affect (NA) and soundscape.

**Keywords:** Soundscape, open office, auditory perception, mood, sound quality

## ÖZET

### AÇIK PLANLI OFİSLERDE İŞİTSEL PEYZAJIN ÇALIŞANLARIN RUH HALİ VE ALIGISI ÜZERİNE OLAN ETKİSİNİN ARAŞTIRILMASI

Volkan Acun  
Yüksek Lisans, İç Mimarlık ve Çevre Tasarımı Bölümü  
Tez Yöneticisi: Doç. Dr. Semiha Yilmazer

Ağustos, 2015

Geçtiğimiz on yıllık sürede, işitsel peyzaj çalışmaları, ses ortamını ayırt etmek için pek yöntem sundu ve bu çalışmalar gösterdi ki ses seviyeleri her zaman en önemli konu değil. Ses kaynakları ile ilişkilendirilmiş anlamlar, bu seslerin dinleyici tarafından algılanışı ve fiziksel ortam, eşit derece önemli. Fakat, işitsel peyzaj prensiplerinin iç mekanlarda uygulanışı ile ilgili çok az çalışma yapılmış bulunmaktadır. Bu araştırmanın amacı açık planlı ofis ortamındaki ses kaynaklarını belirlemek, çalışanların bu kaynakları nasıl algıladığını bulmak ve bunların çalışanların ruh hali ve görev performansı üzerine olan etkisini gözlemlemektir. Bu amaca ulaşmak için, iki farklı açık planlı ofis ortamında ölçümler ve görüşmeler yapılmıştır. Bu çalışma, açık planlı ofis ortamını canlandırmak ve işitsel peyzajın, çalışanların algısını üzerindeki etkisini yakalamak için, subjektif bir yaklaşım olan “Grounded Theory – Köklenmiş Teori” kullanılmaktadır. Çalışanların ruh hallerini değerlendirmek için “Positive and Negative Affect Schedule (PANAS) – Pozitif ve Negatif Etki Çizelgesi” testi kullanılmıştır. Vaka çalışması yapılan ortamların akustik

koşullarını anlamak için, yerinde A-Ağırlıklı Eşdeğer Ses Seviyesi (LAeq) ölçümü, ODEON Room Acoustics Software 13.01 Combined, kullanılarak oluşturulan simülasyon ile de Konuşma İletim İndeksi (STI) ve Çınlama Süresi (T 30) hesaplanmıştır. Köklenmiş Teori'nin bir parçası olarak, 47 çalışan ile yarı yapılandırılmış görüşmeler yapılmıştır. Görüşmelerin sonuçları, çalışanların ofis ortamlarının işitsel peyzajına olan subjektif yaklaşımlarını canlandıran bir kavramsal sistem yaratmak için kullanılmıştır. Oluşturulan bu kavramsal sistem, çalışanların ses kaynaklarını algısını, ses tercihleri, ve yaptıkları iş arasında bağlantıları ortaya çıkartıp, aynı zamanda da işitsel peyzaj ve çalışanların pozitif ve negatif etkisi arasındaki bağlantıyı göstermiştir.

**Anahtar Kelimeler:** İşitsel peyzaj, açık planlı ofis, duyumsal algı, ses kalitesi, ruh hali

## ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to Assoc. Prof. Semiha Yilmazer her encouragement, patience, supervision and guiding me throughout this work. I would also like to thank all examining committee members. I would also like to thank the academic staff of Interior Architecture and Environmental Design Department and the examining committee members for their feedback.

I owe my gratitude to all employees and administrators of Öncüoğlu + ACP Architects and Promer Engineering Consultancy for letting me use their open office spaces for this thesis. Also special thanks for their patience and cooperation during the interviews.

Sincere thanks Özgün Sinal for his assistance with the ODEON Room Acoustics Software and for his company during conference and preparation of this thesis.

I would like to thank Zühre Sü Gül and all the staff of Mezzo Studyo for providing the necessary software and providing help during the pilot study.

I would also like to thank Dr. Burçak Altay with her feedback and support on the Grounded Theory.

Finally, i would like thank my father Bülent Acun as well as my close friends for their smiling faces and endless support throughout my life.

## TABLE OF CONTENTS

ABSTRACT .....	iii
ÖZET .....	v
ACKNOWLEDGEMENTS .....	vii
TABLE OF CONTENTS.....	viii
LIST OF TABLES .....	xi
LIST OF FIGURES .....	xii
CHAPTER 1 INTRODUCTION .....	1
1.1. Aim and Scope .....	3
1.2. Structure of Thesis .....	5
CHAPTER 2 SOUNDSCAPE .....	7
2.1. The Concept of Soundscape.....	7
2.2. Previous Studies Regarding the Evaluation of Soundscape .....	11
2.2.1. Evaluation Methods of Soundscape .....	16
2.2.1.2. Objective parameters Methods .....	16
2.2.1.2.1. Sound Pressure Level (SPL) and Equivalently Continuous Sound Level (Leq) .....	16
2.2.1.2.2. Reverberation Time .....	18
2.2.1.2.3. Speech Transmission Index (STI).....	20
2.2.2. Subjective Survey Methods.....	20
2.2.2.1. Grounded Theory.....	22
2.3. Open Offices Spaces.....	25

2.3.1. Acoustical Factors .....	25
2.3.2. Psychological Factors .....	29
CHAPTER 3 INVESTIGATING THE EFFECT OF INDOOR SOUNDSCAPING TOWARDS EMPLOYEES' MOOD AND PERCEPTION IN OPEN PLAN OFFICES.....	32
3.1. Design of the Study .....	32
3.1.1. Research Question .....	33
3.1.2. Hypothesis.....	33
3.2. Methodology.....	33
3.2.1. Case Study Settings .....	33
3.2.1.1. Öncüoğlu + ACP Architects .....	34
3.2.1.2. Promer Engineering Consultancy.....	35
3.2.2. Objective Measurements.....	37
3.2.3. Subjective Measurements .....	40
3.2.4. PANAS (Positive and Negative Affect Schedule) .....	41
CHAPTER 4 RESULTS.....	43
4.1. Objective Results.....	43
4.1.1. Equivalently Continuous A-Weighting Sound Levels (LAeq) and Reverberation Time (T 30) .....	43
4.1.2. Speech Transmission Index (STI).....	45
4.1. Subjective Results .....	47
4.1.1. Soundmarks .....	53
4.2. Results of PANAS Test.....	54
CHAPTER 5 DISCUSSION .....	59
5.1. Auditory Perception of Soundscape .....	60
5.1.1. What do they prefer to hear? .....	64
5.1.2. Outdoor Sounds .....	69
5.1.3. Soundmarks and Keynote Sounds .....	70
5.2. Employees' Mood .....	71

CHAPTER 6 CONCLUSION .....	74
REFERENCES .....	78
APPENDIX A.....	83
APPENDIX B .....	90

## LIST OF TABLES

Table 1. The list and frequency of sound sources perceived by employees.....	52
Table 2. Results of the Spearman’s rho correlation test.....	56
Table 1: Output of the independent samples T-Test, conducted using IBM SPSS21.....	57

## LIST OF FIGURES

Figure 1. The Taxonomy suggested by Brown et al. (2011) which shows the categories of spaces and categories of sound sources.....	12
Figure 2. Required reverberation time ranges for different types of rooms.....	19
Figure 3. Speech Intelligibility (STI) scale.....	20
Figure 4. Flow chart showing the process of grounded theory.....	23
Figure 5. The prediction schematic, showing the relation between STI and DP (Decrease in Performance).....	27
Figure 6. Determination of radius of privacy, and radius of distraction.....	28
Figure 7. Open office space of Öncüoğlu + ACP Architects.....	35
Figure 8. Main office space of Promer Engineering Consultancy.....	36
Figure 9. ODEON 3D elevation of Öncüoğlu + ACP Architects (Office ARCH).....	38

Figure 10. ODEON 3D elevation of Main office space (Office ENG1) of Promer Engineering Consultancy (Office ENG).....	38
Figure 11. ODEON 3D elevation of subspace (Office ENG2) of Promer Engineering Consultancy (Office ENG).....	39
Figure 12. ODEON 3D perspective of Öncüoğlu + ACP Architects (Office ARCH).....	39
Figure 13. ODEON 3D perspective of Main office space (Office ENG1) of Promer Engineering Consultancy (Office ENG).....	40
Figure 14. Reverberation times for all central frequencies. The dashed rectangle indicates the common speech frequencies.....	44
Figure 15. STI Grid response of open plan office of Öncüoğlu + ACP Architects (Office ARCH).....	46
Figure 16. STI grid response of open plan office of Promer Engineering Consultancy (Office ENG).....	46
Figure 17. Sample taken from the transcriptions, which shows how data is broken down into labels during open coding.....	48
Figure 18. The conceptual Framework.....	50
Figure 19. Soundmarks mentioned by employees of Office ARCH.....	53
Figure 20. Soundmarks mentioned by employees of Office ENG.....	54
Figure 21. STI grid response of the workstations that are located near the meeting room at upper floor.....	62

## CHAPTER 1

### INTRODUCTION

In contemporary world, society tends to disregard hearing, and upraise, what Schafer (1977) calls as “Eye Culture”. Contemporary society, often only pays attention to the sonic environment either when it is too loud or when there is a technological innovation (Truax 2001). There are traditional disciplines, which are scattered throughout, arts, science, engineering and medicine that deals with the behaviour of sound. Yet, when it comes to understand how sound connects with the environment, these disciplines are not enough (Wrightson 1999; Truax, 2001). This field of acoustic communication can only be explored by the interdisciplinary approach of Soundscape (Traux, 2001).

According to the Truax’s Handbook for Acoustic Ecology soundscape can be defined as the “the environment of sound (or sonic environment with emphasis on the way it is perceived and understood by the individual, or by a society”. It is actually a quite old approach but it significant attention is not payed until 1999s (Brown *et al.*, 2011). The term is first introduced by Schafer in his book “*The New Soundscape*”.

Schafer, being a composer and a scholar, worried that individuals perception is dominated by the eye culture and sound is taken for granted. He addressed this issue as the *“sonological competence”*. He asked music students to name five environmental sounds which they hear that day, five sounds that they like and 5 sounds that they don't. In the end he saw that most of the students could not name five sounds even after fifteen minutes (Wrightson, 1999). To address this issue he developed ear cleaning exercises and the soundwalk method, which is widely used in soundscape studies to this day.

Perhaps soundscape can best be summarised as individuals communication with the environment through sound. It is concerned about the context of sound rather than the energy. According to Truax (2001), a sounds' meaning is partly associated with what produces it but mainly associated with the circumstances it is heard. A music, heard in a bar can be accepted and even perceived positive but same music can be very odd in an office because it is out of context. Based on these, it can be said that, soundscape studies provide a new perspective to our sonic environment, a perspective where our awareness of sound is what really matters.

Soundscape studies became the centre of attention in last decade. In 2008, working group of ISO/TC 43/SCI/WG 54 *“Perceptual Assessment of Soundscape Quality of the International Organization for Standardization”* was established to create a standardization for soundscape studies. In 2014, working group published ISO 12913-1:2014, the first part of the standard. This part focuses on the concept of

soundscape by providing an international consensus on the definition of the term “soundscape”. The standard suggests that soundscape is understood as a perceptual construct, related to a physical phenomenon and distinguishes the perceptual construct from the physical phenomenon by clarifying that soundscapes exist through the human perception of the acoustic environment. However, this is still the first part of the standard and most of the studies are concerned with the methods to explore outdoor soundscape while assuming that it is mostly the same for indoor soundscape.

At the moment indoor soundscape research significantly lacks case studies. This study is an attempt to provide more information about people’s perception of indoor soundscape. In order to achieve this goal, a research consisting of measurement/simulation of objective parameters and subjective surveys, are conducted at two open planed office spaces.

### **1.1. Aim and Scope**

Due to their flexibility and cost efficiency, open offices has become perhaps the most popular type of workplace since the middle of 20<sup>th</sup> century. However, they come with a body of problems such as worker dissatisfaction, increased cognitive workload, fatigue, and loss of concentration and lack of privacy (Haapakangas et al., 2011). To address these issues, a standard has been published in 2012, ISO 3382-3 Measurement of Room Acoustic Parameters – Part 3: Open Plan Offices. This

standard specifies measurement methods to provide speech privacy between workstations.

This study aims to address these issues by creating a lived-in experience of an open plan office space to explore employees' perception of their office soundscape. In order to achieve this goal three means of survey has been conducted at two open offices. These methods are; subjective survey, mood tests and objective measurements of acoustical properties of offices. Mood

Grounded Theory is used as the main means of subjective survey. Semi structured interviews are conducted with total of 49 employees'. Interviews are concluded once the collected data no longer produced significant conceptual variations (Corbin & Strauss, 1998; Dey, 1999). After each interview employees are asked to fill Positive and Negative Affect Schedule (PANAS) test which is a mood test.

Objective parameters includes measurement of three main acoustical properties of open office spaces. These are Continuous A Weighted Sound Levels (LAeq), Reverberation Time (T 30) and Speech Transmission Index (STI). T 30 and STI are calculated from a computer simulation using Odeon Room Acoustics Software while LAeq is determined through in-situ measurements. These objective parameters are used to see the acoustical conditions of case study settings and to compare with the subjective survey and mood test.

## **1.2. Structure of Thesis**

Study consists of six chapters. The first chapter is Introduction, which gives the main idea about the thesis. It briefly describes the subject, why it is significant, and what is the scope and what is the aim of the study.

Second chapter is the literature review part of the thesis. This chapter is designed to give information about the concepts that will be used throughout the study. It is divided into three sections. First section titled "Concept of soundscape" explains the emergence of this concepts, the underlying themes, its significance, and features of soundscape. Next section gives examples from significant studies briefly, and explains the methods used to evaluate soundscapes. This section is aims to provide a prior knowledge about the evaluation methods. It is intended to be reference for the following sections, a section which gives the definitions of the methods that will be seen further in thesis. Last section of literature review explains the significant acoustical parameters within an office space. This section also provides information and case studies about psychological factors of mood, emotion, and affect.

Third chapter explains the design of the study and methodology. Research questions and hypothesis can be found within in this chapter. Methodology

describes the case study setting, and explaining the research procedures by telling why certain research methods are used.

In the fourth chapter, results of the study are presented under two sections; Objective measurements is the first section, which provides the findings of simulations and in-situ measurements. Second section presents the findings of subjective survey, which consists of, Grounded Theory, and PANAS. As it was mentioned previously, soundscape is about individuals' awareness of his sonic environment. In order to reflect this as clearly as possible employees' exact answers during the interviews are quoted when it is necessary.

Discussion chapter compares the findings of this research with previous ones and elaborates significant findings to understand the underlying phenomenon.

Throughout this chapter, employees' answers are quoted, to clearly reflect employees' awareness of their sonic environment. Thesis ends with Conclusion chapter, which summarises the whole research, and refers to possible future studies.

## CHAPTER 2

### SOUNDSCAPE

#### 2.1. The Concept of Soundscape

The World Soundscape Project started at 1969 by R. M. Schafer of Simon Fraser University. Projects aim was to find an ecological harmony between the human community and its sonic environment (Westerkamp, 2006). The project raised public awareness of sound, exploring, and documenting the environmental sound and its changing character, and established the concept and practice of soundscape design (Westerkamp, 2006). It is considered as the foundation of the acoustical ecology studies or, as its more common name, the soundscape studies (Westerkamp, 2006; Wrightson, 1999). Many of the seminal works are published from this study such as, *The Tuning of the World*, *The Vancouver Soundscape*, and *The Handbook of Acoustic Ecology*.

The term “soundscape” indicates how the environment is understood by the listener (Truax, 2001; Schafer, 1988; Westerkamp, 2006). As the listener is also the

sound maker, when we step into an environment we inevitably affect the environment, and the environment affects the way we perceive sounds. World Soundscape Project showed that there is a delicate relationship between listening and sound making. This balance can be used to measure the quality of a sonic environment (Westerkamp, 2006). An imbalance between listening and sound making can be seen in situations where, what we hear is louder than our own sound.

Soundscape approach considers the listener and environment together, not as isolated entities. Listener within a sonic environment engages in a dynamic range of information exchange. The major difference between soundscape and the traditional energy transfer approach is, one of them is concerned with the acoustical communication, the individual's communication with the environment through sound, whereas the other one is concerned with the transfer of energy. Truax explains their difference with the classic expression of "if a tree falls in a forest..."

"The tree falling in the forest creates a momentary series of energy transfers whether it is heard or not. Within a communicational framework we will be much more concerned about the information communicated by the sound of that tree (Truax, 2001)."

Schafer (1977) based his theory of soundscape on three foundations; philosophy of music, ecological consciousness and aural culture. In his book "Tuning of the World", he proposed a typology for sounds, which divides sounds into three groups. He defined background sounds as "keynote sounds", a reference to music theory

where keynotes identify the fundamental tonality of a music (Schafer, 1977; Wrightson, 1999). Signal sounds refer to the foreground sounds such as fire alarms. And lastly, soundmarks, a reference to landmarks. Just as the landmark is used to define the space it is associated with, a soundmark is also associated with a certain environment. An example could be the sound of a distinctive church bell.

Just like a certain community's architecture and customs are associated with its identity, typology of sounds reflect identity of a local environment which can be recognised and characterised by their soundscapes (Wrightson, 1999). However, since the industrial revolution the unique soundscapes started to become homogenised. What is meant by homogenised is, with the rise of the mechanised world the more quite sounds get masked by louder sounds. Most common example is the soundscape of a city with its dominant keynote, traffic.

Aware of this situation, Schafer described it with the term "hi-fi" (high fidelity) and "lo-fi" (low fidelity). Hi-fi is used to describe environments in which the sounds overlap less frequently, environments more like the pre-industrial era (Schafer, 1977). Lo-fi is the environment in which the sounds are more homogenised (Schafer, 1977).

While transcribing the recording of World Soundscape Project, researchers discovered that sounds within a natural environment has a rhythmic balance which

led to Krause's "Niche Hypothesis" (1993). Krause stated that, in a natural environment, a sound of mammal or bird fit in relation to all natural sounds in terms of frequency and rhythm. Sounds of each animal and insect occupies small bands of frequencies leaving "spectral niches" into which vocalisations of other animals and insects can fit in. Therefore, on contrary to soundscape of cities, in a natural environment sounds do not mask or block each other, creating a more perceptual sonic environment. Just like the way individuals communicate with environment through sound, animals do the same. Krause's theory suggests that these niches between frequencies are used by animals to fit in mating calls.

In hi-fi soundscapes, sounds from each frequencies can be heard distinctively. This provides listeners significant amount of information about the physical nature of environment, the context and a sense of place. Truax states that the travelling sound waves are charged each time it interacts with the environment, thus providing information about the physical environment.

On the other hand, in lo-fi soundscapes, due to the homogenised nature of sonic environment, meaningful sounds can be masked. This may even cause an individual to not being able to hear the reflected sound of his/her movement or speech and by creating a "sound wall" (Schafer, 1977) and becoming isolated from the sonic environment (Wrightson, 1999).

## 2.2. Previous Studies Regarding the Evaluation of Soundscape

Soundscape studies started nearly 40 years ago. However, significant attention to the subject is not paid until late 1990's. As it was stated, currently the working group of ISO/TC/43/SC1 is working towards a standardization of the concept and evaluation of soundscape.

In their paper "Towards standardization in soundscape preference assessment", Brown *et al.* (2011) represents authors personal view and suggestions based on the studies of working group of ISO/TC 43/SC1, the group which studies the standardization of soundscape. This point of view provides a valuable insight about the standardization of soundscape evaluation. They set the focus of soundscape studies as the acoustic environment of any place. They suggested to utilize the term of soundscape as both "acoustic environment of sounds, as perceived by humans" and "the total collection of sounds". Authors put emphasis on identification and description of sound sources because it gives valuable information about the soundscape of that place as the sound sources can be perceived differently from place to place. In order to do this, authors suggested a taxonomy of the acoustic environment (Figure 1). This taxonomy categorises acoustic environment as indoor and outdoor acoustic environment, while assuming that principles used in outdoor studies also apply to indoors.

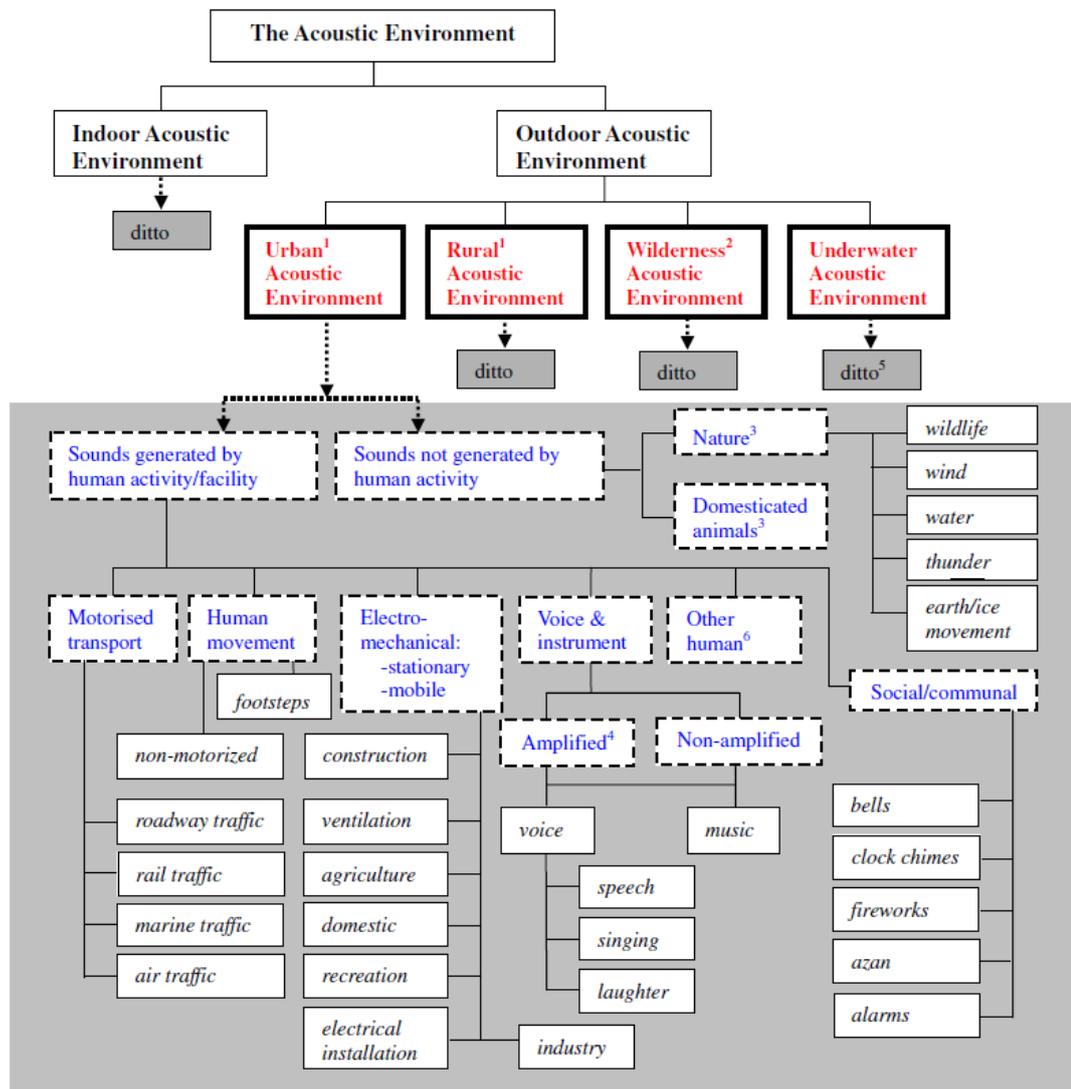


Figure: The Taxonomy suggested by Brown et al. (2011). It shows the categories of spaces and categories of sound sources.

Fiebig and Schulte-Fortkamp (2004) used grounded theory to create a common perceptive pattern as it provides means to systematically analyse the qualitative data. Mackrill *et al.* (2013) also used this approach to create a conceptual model that shows patients and nurses perception of a hospital ward.

Research conducted by Brambilla *et al.* (2012) aimed to categorize urban places by means of acoustic descriptors and analysis of relationship between features of objective parameters and subjective laboratory measurements. Researchers conducted soundwalks to record the soundscape of 20 squares in Rome.

Researchers used the recordings for their laboratory study, where they carried out sound recognition and semantic differential tests. They analysed the results using cluster analysis. As Objective parameters, they used LAeq. Authors concluded that soundscape quality assessment can be more comprehensively examined by merging field measurements of physical parameters with subjective ratings of laboratory and/or field.

In a different study, Brambilla *et al.* (2013) used psychoacoustic parameters, objective measurements of sound levels and face to face interviews to investigate the user's perception of environmental quality in parks and its relationship with acoustical parameters. They concluded that the sound environment in urban parks are often rated as "good" or "excellent" even if the sound levels are higher than it is supposed to be. Researchers suggested that this can be due to the presence of natural features that gives a sense of tranquillity.

Yang and Kang (2013) also used psychometric parameters to study the characteristics of various natural and urban environmental sounds and examine their differences. They concluded that sound categories cannot be identified using a single acoustical or psychoacoustical parameter but rather with a group of

parameters. They categorized urban sounds in four main groups, birdsong, wind, water, and urban.

Research carried out by Okcu *et al*, in 2011, aimed to determine if objective noise levels and subjective perceptions differ. Their study focused on the comparing ICUs of two hospitals, one being rather old and other one being new. They used LAeq as the main tool of objective measurement. For the subjective measurement, researchers conducted a questionnaire survey. This questionnaire consisted of, noise annoyance, perceived loudness and work performance questions. This study revealed that even though, there are very little difference between the objective measurements, one of the ICUs is perceived louder, more annoying and has greater negative impact of noise towards work performance. Therefore, the results indicated that the traditional overall noise measurements may be inadequate to capture the differences between perceived annoyance, loudness and performance.

Dökmeci and Kang (2012), used objective and subjective analysis to explore the indoor soundscape of three libraries in Sheffield. They used sound measurements and socio-acoustic questionnaires. Their aim was to understand the objective sonic environment through the acoustic and psychoacoustic parameters and compare it with the perceived evaluation results to explore different factors affecting soundscape perception. They concluded that objective parameters such as sound pressure level (SPL) and loudness (N) are significantly related with subjective evaluations of the soundscape.

Another research about hospitals is conducted by Mackrill et al (2013), which used grounded theory to explore patients and nurses perception of the cardiothoracic ward of a hospital. This study is a major inspiration for this thesis. Researchers applied a user focused approach, which aimed to conceptualize the lived experience of soundscape from patients and nurses, discovering positive and negative aspects. This research also used objective and subjective measurements however, objective measurements are only used to give a general idea about the acoustical conditions of the space. Results showed that, information given about a specific sound can ease the negative feelings towards it. Individuals can also develop coping methods such as habituating or accepting the negative sounds sources. Just as it was stated by Truax (2001) in “Acoustical Communication”, the context of sound has significant importance towards the perception of sonic environment. Patients are more likely to accept a certain sound when they can understand it. Their research also suggested that physical and cognitive interventions could make the soundscape perceived more positively.

Following up on their findings in hospital soundscape study, Mackrill et al (2013), used laboratory listening evaluations to rate participants’ emotional (relaxation) and cognitive (understanding and interest) responses to a variety of hospital soundscape clips with three interventions. One of the significant findings is, relaxation response is affected by the natural sound interventions by produce 10.1% more positive response. In the end, authors suggest that improving the

sounds of a hospital ward provide subjective benefits that cannot be achieved by sound level reduction.

### **2.2.1. Evaluation Methods of Soundscape**

Through the course of soundscape studies, researchers used variety of different approaches to evaluate soundscapes. There are three main approaches, objective parameters, subjective survey and psychoacoustic survey. Each of these approaches consist of various methods and it is very common among researchers to use combination of different approaches.

Following chapters will explain the objective parameters and subjective survey methods, with emphasis on the methods chosen for this research. As psychoacoustic survey is not within the scope of this research, there aren't any chapter explaining its methods and features.

#### **2.2.1.2. Objective parameters Methods**

##### **2.2.1.2.1. Sound Pressure Level (SPL) and Equivalently Continuous Sound Level (Leq)**

SPL is defined as “the logarithmic measure of the RMS sound pressure of a sound relative to a reference value, the threshold of hearing.” Leq is similar to SPL,

however, it is the total amount of sound energy over a given time period.

Measurement unit for both of them is the logarithmic scale unit of dB and it is measured by Sound Level Meter.

Human ears can detect the frequencies between 20Hz to 20 000Hz. However, it is more responsive to certain range of frequency which is between 500Hz and 6000Hz.

Human ears are less sensitive to very low and very high frequencies. Frequency weighting is a method that is used to capture humans' subjective response to the objective sound levels. The most common weighting type is the A-Weighting. Just like the human ears, this weighting type is less sensitive to low audio frequencies and it can reflect human response more accurately than other weightings and SPL. The A-weighted measurement of  $L_{eq}$  is shown as  $L_{Aeq}$ , and the measurement unit for both SPL and  $L_{Aeq}$  is shown as dB(A).

Occupational Health and Safety regulations of OSHA (Occupational Safety and Health Administration of United States) limits exposure to 90 dBA for all workers for an 8 hours a day. As it can be seen, this limit is mostly concerned with workplaces involving hard labour, where sound levels can become very high. Sound levels in a typical office is between 50 to 60 dB(A).

#### 2.2.1.2.2. Reverberation Time

Reverberation time (RT 60) is the time required for sound to decay 60 dB from its initial sound level (Egan, 1988). It is introduced by Wallace Clement Sabine at 1895. Sabine's goal was to improve the listening conditions in lecture halls. The method Sabine introduced correlates the total volume of the room with the total sound absorption coefficients of materials within the room. The following formula is known as the Sabine Formula, which is used to measure the reverberation time of any given space.

$$T60 = 0.161 \times v/a$$

In this formula:

T60: is the time required for 60 dB decay of sound;

v: is the total velocity of the room;

a: is the total amount of absorption of room

However, Sabine's formula ignores air absorption which can be significant for large halls. Rossing (1990) proposed a modification to this formula to include air absorption. Air absorption is greater at higher frequencies and also depends on the humidity of space. Formula modified by Rossing can be seen below, with  $mV$  representing the air absorption coefficient (Appendix Table A 1).

$$T60 = 0.161 \times v/a + mV$$

There are also other formulas to measure reverberation time, such as the *Eyring Formula*. However, these methods of measuring reverberation time are only used for special conditions such as, for recording studios or anechoic chambers, which have very high amount of absorption (Egan, 1988). Reverberation requirements of a room depends on the activity (Figure 2). Larger rooms require higher reverberation time while smaller rooms require lower (Egan, 1988).

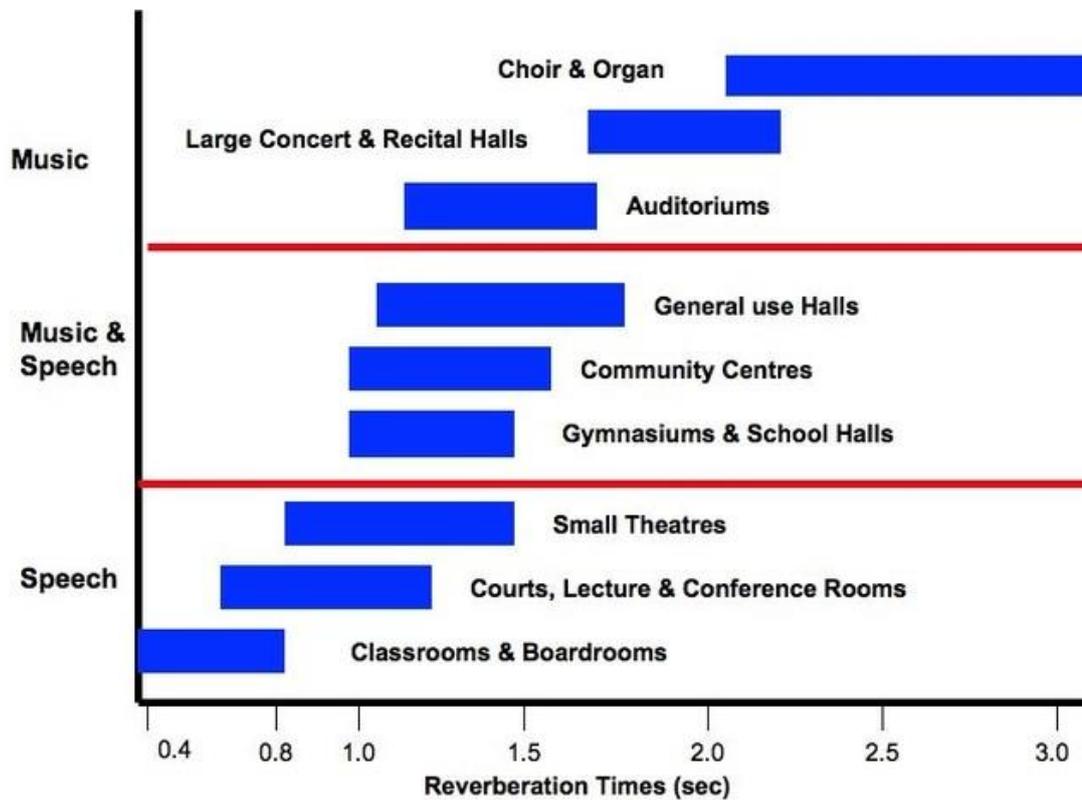


Figure 1: Required reverberation time ranges for different types of rooms (“Reducing a rooms,” n.d.).

### 2.2.1.2.3. Speech Transmission Index (STI)

Speech transmission index is the measurement unit of quality of speech intelligibility (Egan, 1988). It ranges between the scale of 0 to 1, with “1” referring to excellent intelligibility and “0” referring to bad intelligibility (Figure 3). There is also another scale proposed by Barret (1995) known as Common Intelligibility Index (CIS).



Figure 2: Speech Intelligibility scale (Acousticator, 2012).

### 2.2.2. Subjective Survey Methods

Various approaches are used to capture individual’s subjective response to the soundscape. Some of these approaches are; sound preference tests, semantic differential scales and noise annoyance surveys. As the name suggests, sound preference test is concerned with the sounds preferred or unwanted by individuals. Sound preference can vary depending on age and gender.

Sound annoyance is the negative evaluation of environmental conditions due to their association with disturbance, aggravation, dissatisfaction, concern, bother, displeasure, harassment, irritation, nuisance, vexation, exasperation, discomfort, uneasiness, distress, negative evaluation of sound source and high sound levels

(Koelega, 1987; Guski *et al.*, 1998). As the sound annoyance changes from person to person there isn't any method specific survey method other than noise annoyance questioners or interviews.

Semantic differentials is a rating scale that consists of adjective pairs. Subjects are asked to choose between one of the adjectives from each pair. In acoustics, subjects are expected to judge the sound by means of adjective pairs such as quiet or loud, pleasant or unpleasant. These pairs of adjectives are decided according to findings of pilot studies and soundscape literature (Ozcevik & Yuksel, 2012). The findings of semantic differential test and questionnaires are analysed by using statistical analysis software to find out about statistical reliability of opinions, attitudes and values.

Sound walk method is one of the most iconic method to evaluate a soundscape. Like most of the concepts regarding soundscape, it is introduced by Schafer. This method is used, in order to judge sound based on its components and perceptibility. It is a procedure of focused listening, in which the participants move through the environment with complete attention to their sonic environment. Participants can be guided with written or oral instruction and they may also be walking with a blindfold, stand still or move in response to the sound field (Basco, 2011). There are different adaptations of soundwalk method, but at this point none of them are suitable to be used indoors.

This thesis uses “Grounded Theory” as the main subjective survey method.

Grounded Theory provides a broad scope and flexibility to conduct a research, which can explore some of the most common subjective survey methods above such as noise annoyance and sound preference. The following section will provide detailed information about the aspects of grounded theory.

#### **2.2.2.1. Grounded Theory**

Grounded Theory is a qualitative research method that aims to generate or discover a theory (Corbin & Strauss, 1998; Dey, 1999). It is introduced by Barney Glaser and Anselm Strauss in 1967 and they briefly describe it as “The discovery of theory from data”. In fact the name “Grounded Theory”, comes from the fact that theory is derived as the research advances, in a way the theory is grounded to the data (Corbin & Strauss, 1998).

Grounded theory uses interviews, documents, and observations, as means to collect data. Data analysis is systematic and begins as soon as the data becomes available. Data analysis consist of identifying categories, defining patterns and connecting them to derive concepts (Figure 4). The data collecting stops when data no longer

produces any significant categories, which is called the “Theoretical Saturation Point” (Corbin & Strauss, 1998; Dey, 1999; Jones & Alony, 2011).

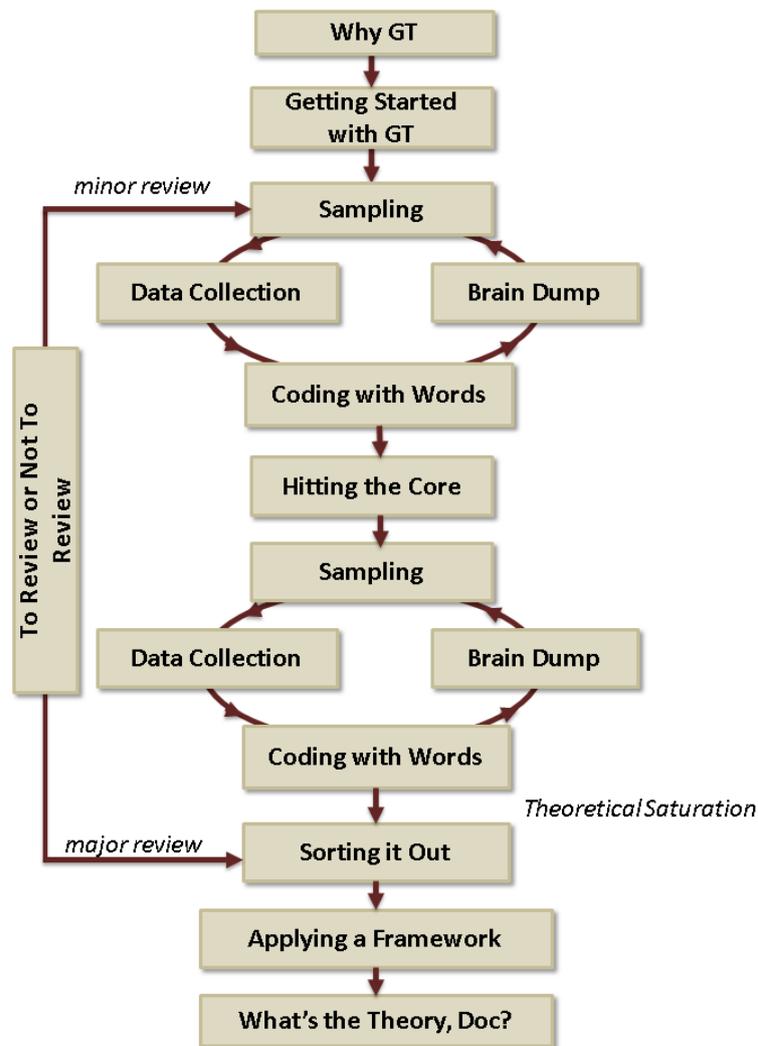


Figure 3: Flow chart showing the process of grounded theory (Hoda et al. 2011).

Glaser and Strauss described the analysis of data as “constant comparative” method. Coding is the major tool of analysis which has three stages. First one is the “Open Coding”, where the data is broken down in to pieces to generate categories.

In “Axial Coding”, researcher looks for patterns between these pieces and put them together. This stage of coding can be described as building a puzzle, researcher has to compare categories constantly with each other to understand where a certain piece goes. At the end of this phase categories grouped together to form themes. Last stage of coding is the “Selective Coding”. In these phase a core theme/category is selected and searched for relations with other themes. Theory is generated after this phase. Strauss and Corbin define it as:

“...the process of selecting the core category, systematically relating it to other categories, validating the relationships, and filling in categories that need further refinement and development (Strauss & Corbin, 1990:116).

Grounded theory is one of the most popular research methods among social science studies. It works quite opposite than the traditional social science research methods. Instead of finding an existing framework and applying tests to figure out whether this framework applies to the phenomenon, researcher begins the study with a question, with almost no prior knowledge about the phenomenon (Corbin & Strauss, 1998; Dey, 1999). It is concerned with generating a theory rather than testing one. Popularity of grounded theory comes from its strong and successful institutional support, its flexibility and its ability to zero in to a specific subject with almost no requirement of prior knowledge (Hoda *et al.* 2011).

### **2.3. Open Offices Spaces**

Open-plan offices are one of the most popular workspace layouts. They are believed to promote communication and interaction between employees along with the advantages of, increased net usable area, higher occupant density and ease of reconfiguration ( Hongisto et al., 2004; Kim and de Dear, 2013).

However there is no empirical evidence showing that open plan layout will increase task performance (Kim and de Dear, 2013). In fact they are associated with lack of speech privacy and uncontrolled sounds levels which can cause significant decrease in task performance and workplace satisfaction (Jahncke *et al.*, 2013; Kim and de Dear, 2013).

#### **2.3.1. Acoustical Factors**

The most common type of sound within an office is speech. An appropriate room acoustic design for an open planed office requires that the distraction by speech is sufficiently controlled (Haapakangas et al., 2011). In order to provide this, several factors are needed to be considered. These factors can be listed as; absorbers on ceiling, walls and furniture, high screens and storage units, distance between workstations, enclosure of workstations and the use of artificial masking sound

(Bradley, 2003; Virjonen *et al.* 2009). All of these factors are associated with reduction of sound levels. However, “artificial masking sound” is about providing negative speech-to-noise ratio, which is the difference of levels of speech and background noise (Haapakangas *et al.*, 2011). Negative speech-to-noise ratio corresponds to a less intelligible speech.

Overall noise levels are not always the most important issue regarding the sound quality of an open office (Jahncke *et al.* 2013). Intelligibility of background speech is also an important factor (Hongisto, 2005; Kitapçı, 2008; Haapakangas *et al.*, 2011; Jahncke *et al.* 2013). Background speech can cause interference-by-process account of auditory distraction; this type of distraction is caused by a conflict that emerges between similar, competing processes (Jahncke *et al.* 2013). Involuntary processing of speech causes distractions on tasks that require similar process. Previous studies have shown that if a task involves processing of semantic information, it becomes more vulnerable to speech sounds (Jahncke *et al.* 2013).

A prediction model proposed by Hongisto (2005) shows the amount of performance loss with relation to the STI. According to the schematic prediction model, STI values higher than 0.6 can decrease the task performance by 7% (Figure 5). However, between the STI ranges of 0.60 to 0.20 negative effect on task

performance significantly reduces. After 0.20, intelligibility of the speech comes down to a point where it hardly effects work performance.

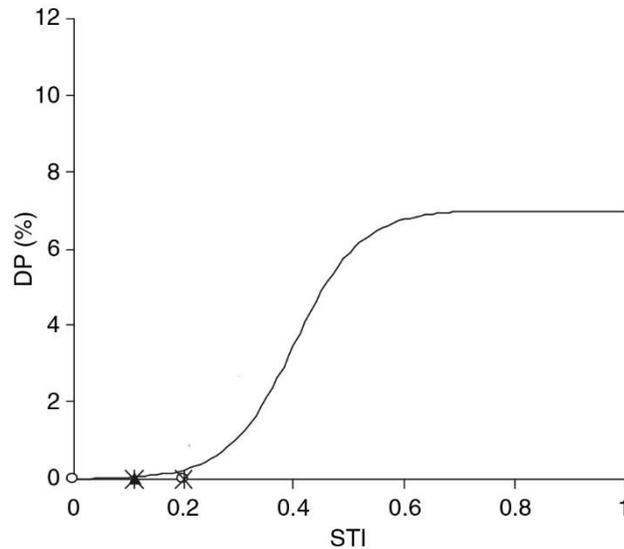


Figure 4: The prediction schematic introduced by Hongisto (2005), showing the relation between STI and DP (Decrease in Performance)

ISO 3382-3 Measurement of Room Acoustic Parameters – Part 3 Open Plan Offices, provides two significant STI parameters for open plan offices; radius of distraction ( $r_D$ ) and radius of privacy ( $r_p$ ). Radius of distraction is the distance from the sound source where STI value drops below 0.50. Below this value, concentration and privacy conditions starts to increase rapidly. Similarly, radius of privacy is the distance from the speaker where STI drops below 0.20. An example showing the determination of radius of distraction and radius of privacy can be seen at figure 6.

At this point, intelligibility of speech is approximately equal to that of a single office room. There are obvious similarities between the values of ISO standard and the

study carried out by Hongisto, as his research contributed the preparation of this standard greatly.

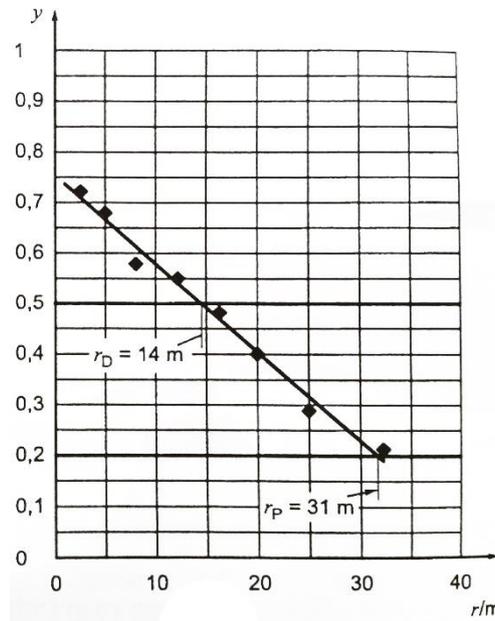


Figure 5: Determination of radius of privacy ( $r_p$ ), and radius of distraction ( $r_D$ ). In the above graph,  $y$  represents the STI value and  $r$  represents the distance from the source (ISO, 2012).

Research done by Kim and de Dear (2013) showed that noise levels and speech privacy, are among the major problems of open planned offices, along with visual privacy. Same study also showed that exposure to noise and lack of speech privacy does not only cause performance loss but it also decreases the workplace satisfaction significantly and sound interference causes increased distraction among open plan office employees.

As the speech is the most annoying sound source within an office, speech privacy between work stations should be as high as possible. Research conducted by Hongisto *et al.* (2004) aimed to present a simple and validated model that can

predict the STI between two workstations. Their model uses signal-to-noise ratio to determine speech intelligibility by providing STI and rapid speech transmission index (RASTI).

### **2.3.2. Psychological Factors**

Mood, affect and emotions considered to be among the fundamental issues in human psychology. However, it is hard to distinguish them from each other as they all belong to the same psychological background, which is referred to as the "*Affective Phenomenon*" or "*Affective Science*" (Ekkekakis, 2013).

The term *affect* refers to a fundamental feeling state in human mind. According to Wundt (1997) people are "never in a state entirely free from feeling". On the other hand, researchers argue whether a state of feeling can be achieved consciously or not (Schnall, 2010). The one aspect of affect, which everybody mostly agrees upon is that, affect comprises both emotion and mood. So it can be said that affect is a main element which also includes emotions and moods within itself, therefore, affect can refer to subjective responses of moods or emotions.

Affect has three qualities which are; pleasantness/unpleasantness, called the valence, arousing/subduing, called the arousal, and strain/relaxation called the intensity (Barret & Bliss-Moreau, 2009; Schnall, 2010). These three qualities are the

indicators of a unified state. In order to describe an individual's momentary mental state valence (pleasant or unpleasant) and arousal (arousing or subduing) are used, which provides the basic psychological primitive, common for all psychological states. This psychological primitive is called the *Core Affect*. Core affect can be a component of emotions and moods or, it can also occur in pure, or isolate form (Ekkekakis, 2013).

Emotions can be defined as a complex set of interrelated sub-events concerned with a specific object (Russel & Barret, 1999). Emotions are either elicited by something, reactions to something or generally about something, therefore the transaction between the individual and object is defined by the cognitive appraisal (Ekkekakis, 2013).

Mood, on the other hand, is an affective state, that lasts longer than emotions (Schnall, 2010; Ekkekakis, 2013). A mood can be about everything or about nothing specific (Ekkekakis, 2013). For example a person is in an anxious mood, this can be about the business meeting he will attend later that day or can be anxious about the future and when a person is in an irritable mood, object of this can be anything and anyone (Ekkekakis, 2013).

There are several ways to measure mood. One of the most frequent one, and the one chosen for this research, is Positive and Negative Affect Schedule (PANAS). This

test measures the two primary dimensions of mood, positive and negative affect. As it was mentioned above affect consists of three qualities. In PANAS test, positive affect reflects the extent in which an individual feel pleasant, active and alert. So it can be said that positive affect indicates pleasurable engagement. On the other hand, negative affect reflects the extent in which a person feels unpleasant and distress, which indicates unpleasurable engagement.

While there aren't any case studies that explores the relation between employees' mood and sonic environment, there are important studies that associate task performance and mood. Isen *et al.* (1987) found that positive affect increases problem solving by influencing the way material is processed, combine them and see relations between stimuli. Research conducted by Martin and Kerns (2011), suggests that positive mood can increase the visual scope of attention and has effects on cognitive control and impairing working memory.

There is also evidence, suggesting that the colour of a workspace effects mood. Kwallek *et al.* (1996) colour scheme of an office space alone may have an impact on employees' mood

## **CHAPTER 3**

### **INVESTIGATING THE EFFECT OF INDOOR SOUNDSCAPING TOWARDS EMPLOYEES' MOOD AND PERCEPTION IN OPEN PLAN OFFICES**

#### **3.1. Design of the Study**

This study aims to conceptualize the lived in experience of an open office space to explore the factors that contributes to employees' perception of the soundscape of their work environments. Research is conducted at two medium sized companies. Means of objective and subjective survey are used together. Objective parameters consists of, the in-situ sound level measurements (LAeq) within working hours and calculation of reverberation time (RT 30) and Speech Transmission Index (STI). Grounded Theory is adopted as the main research method of this thesis. Semi-structured interviews are conducted with employees to derive themes and create a conceptual framework that shows factors contrubuting to the perception of indoor soundscape. Descriptive statistic, mainly frequency tables, are used to show various results derived from the interview transcriptions. Şastşy, Positive and Negative Affect Schedule (PANAS) test is used evaluate employees' mood.

### **3.1.1. Research Question**

Grounded theory suggests starting the research with a very brief question, in order to not limiting the scope of the study (Corbin & Strauss, 1998; Dey, 1999; Jones & Alony, 2011). As grounded theory is not about testing a hypothesis but creating a theory, doing so will provide a broader perspective towards understanding the phenomenon. Therefore, this research has one research questions that involves multiple aspects of the phenomenon.

Does indoor soundscape quality effect employees' mood, and perception of their office environment?

### **3.1.2. Hypothesis**

The hypothesis of this study is; the indoor soundscape effects employees', mood, and perception of their work environment.

## **3.2. Methodology**

### **3.2.1. Case Study Settings**

Semi-structured interviews and in-situ measurements are conducted within the open office spaces of two different companies.

### 3.2.1.1. Öncüoğlu + ACP Architects

First company is Öncüoğlu + ACP Architects. Even though it is in a very central location in Ankara / Turkey, it is located within a quiet and secluded residential block. Company owns the basement, ground floor and the first floor of a residential block. Open office space is within the ground floor, along with the more traditional office of the accounting department. Rest of the floors are used for services and management. The company has more than thirty employee, but only around 25 works within the open office space.

The main office area is a 215 m<sup>2</sup> space (Appendix Figure A 1). This space consists of the open office space at one side and the private offices of more senior employees on the other side. Main office has two different ceiling levels. Majority of the open office space has ceiling height of 5.79 meters while other part has ceiling height of 2.40. Higher part of the ceiling is covered with, Metapan Multipanel, linear ceiling panels with acoustical properties. This material covers total of 105 m<sup>2</sup> of ceiling area, other part is covered with plaster. Floor material is vinyl throughout the office space and wall material is plaster on paint. Northern wall also has windows with dimension of 3.59m x 1.1m, covering 19.8 m<sup>2</sup> of wall in total (Figure 7). The partitions between employees desk consist of fabric, which is not only used for acoustical purposes but also used by employees to attach all kinds of documents.



Figure 6: Open office space of Öncüoğlu + ACP Architects.

### **3.2.1.2. Promer Engineering Consultancy**

Second company is Promer Engineering Consultancy. Their office is a four storey building, located in the residential district of Ümitköy/Ankara. Company uses two floors as office space while using the rest for management and services. The spaces used as office has identical plans. The company has, around fifty employee, majority of them working in open office spaces.

The open office space is 135 m<sup>2</sup> per floor (Appendix Figure A 2). Similar to the former company, there are also private offices for in each floor but they are not included in the given measurement of area as they are not really located within the open office area but in a corridor leading to it. The open office space is divided into

two parts; a main space with around fifteen employee and a subspace with six employee. Materials of the office space are; epoxy for floor material of whole building and, paint on plater for walls and ceiling. Ceiling high is same across all office, which is 2.60 meters. There aren't any sound absorbing material except for the blackouts of windows. Even the partitions between desks are acrylic.



Figure 7: Main office space of Promer Engineering Consultancy.

In order to make it more clear, Öncüoğlu + ACP Architects will be referred to as Office ARCH, as in architecture and Promer Engineering Consultancy will be referred as Office ENG.

### **3.2.2. Objective Measurements**

In order to analyse the acoustical characteristics of the office spaces, a combination of in-situ measurements and Odeon Room Acoustics Software 13.01 Combined are used (Figures 9-12). In-situ measurements are conducted for two days, during working hours and while the offices are occupied. Bruel & Kjaer Sound Level Meter type 2230 is used for measurements. Sound level meter is placed at central locations of both offices at the height of 125cm and measured over 15 minute time intervals. In Office ARCH some workstations were no longer used by the employees' during the time of measurements, thus in-situ measurements are conducted on the occupied part of the office. As for Office ENG, in-situ measurements are conducted at both floors. Sound Level meters is placed at a central location in main office space and later a location between the subspace and the printer room. This is intended as to capture the sound coming from both the main office space, subspace and printer room.

3D models of both offices are prepared at SketchUp 14 and imported to Odeon Room Acoustics Software 13.01 Combined, which provided the Speech Transmission Index (STI) and Reverberation time (RT 30). Due to the plan of Office ENG, two separate models are prepared, one for the main space and other for the subspace. This decision is made to acquire more accurate data from simulation.

Results are later compared with employees' answers to the semi-structured interview.

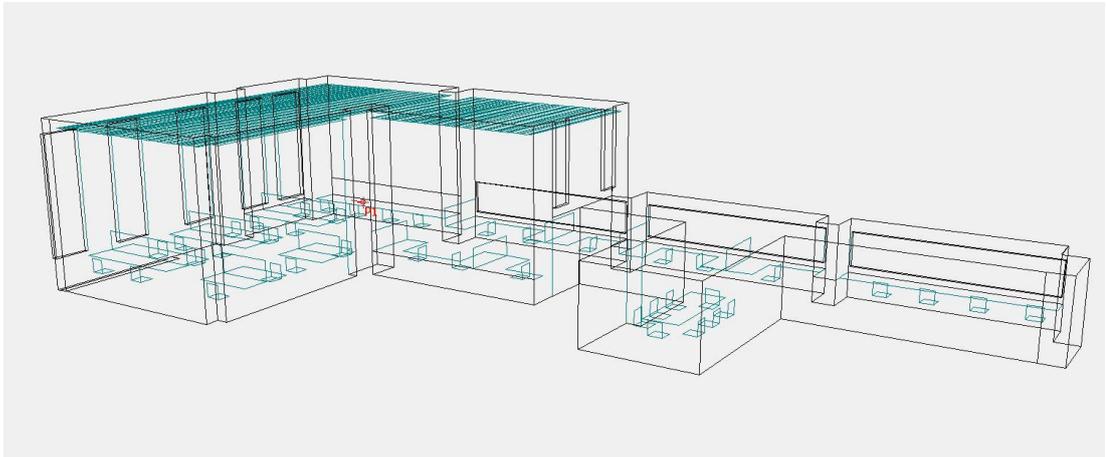


Figure 8: Main office space of Promer Engineering Consultancy.

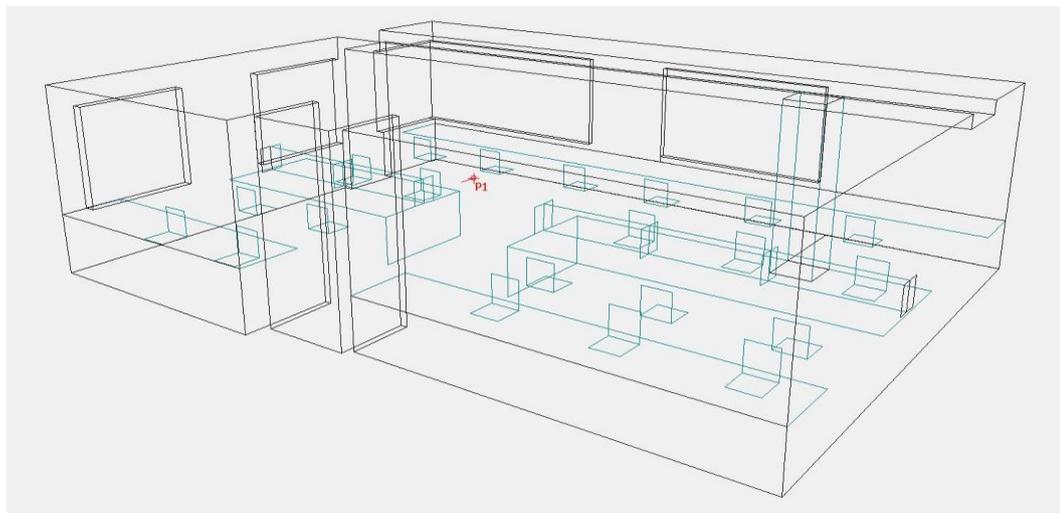


Figure 9: ODEON 3D elevation of Main office space (Office ENG1) of Promer Engineering Consultancy (Office ENG).

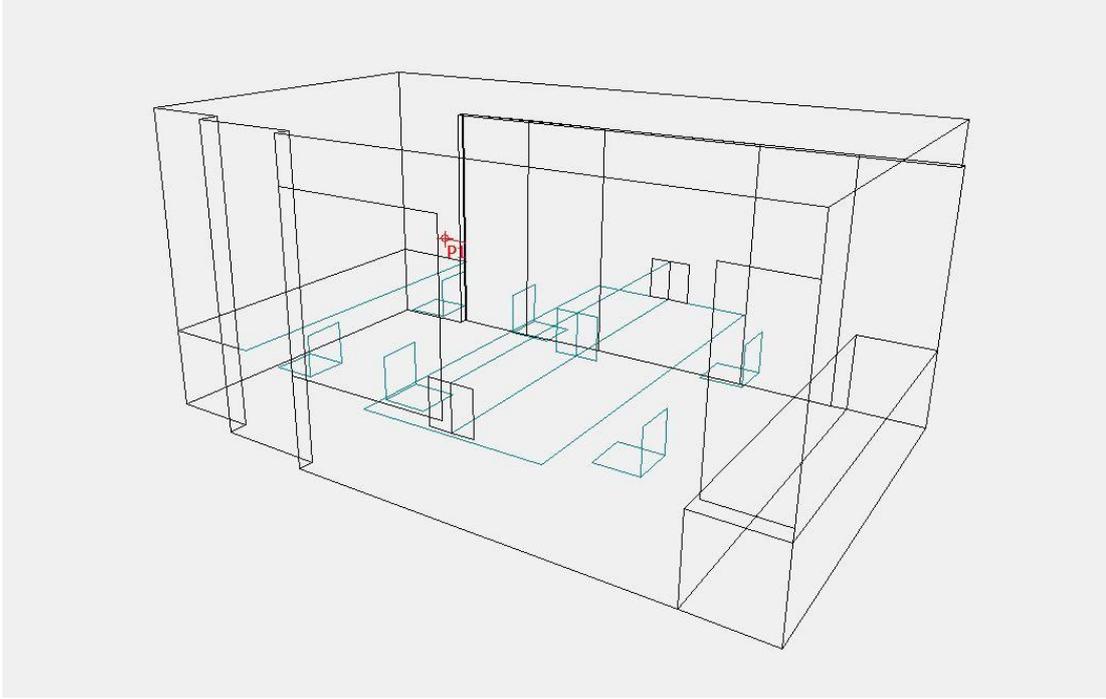


Figure 10: ODEON 3D elevation of subspace (Office E2) of Promer Engineering Consultancy (Office E).

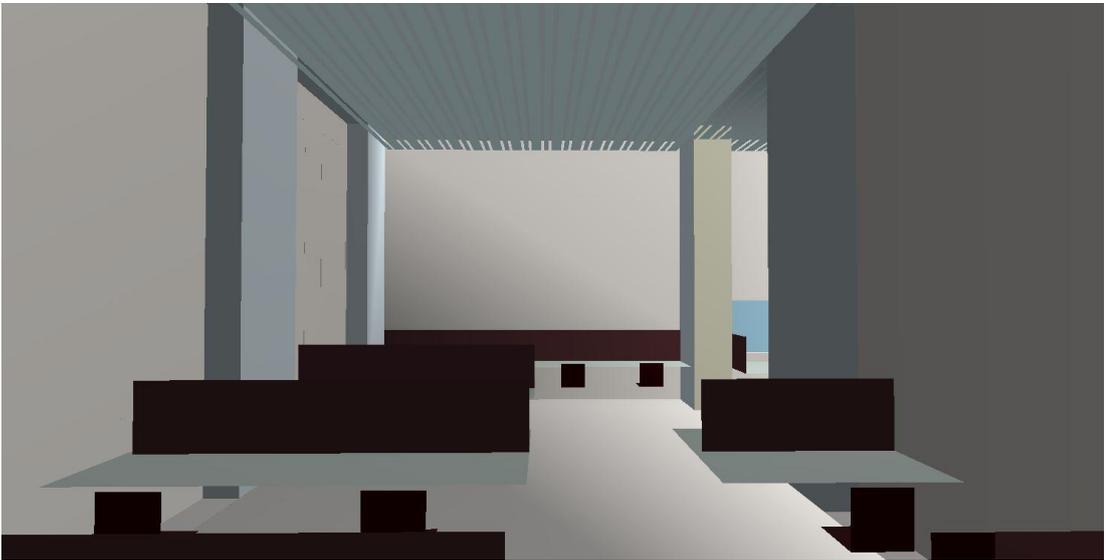


Figure 11: ODEON 3D perspective of Öncüoğlu + ACP Architects (Office E).



Figure 12: ODEON 3D perspective of Main office space (Office ENG1) of Promer Engineering Consultancy (Office ENG).

### 3.2.3. Subjective Measurements

Grounded Theory is used as the main means of subjective survey. Semi structured interviews are conducted with 47 employees, 23 from Office ARCH and 24 from Office ENG. Interview process started with 7 core questions (Appendix Figure B 4), which are prepared based on previous studies, mainly to *“Positive Soundscape Project”*, conducted by Davies et al. (2013). However, the questionnaire needed adjustments as this is study is concerned with indoor spaces.

These questions are meant to be very generic and aims to direct the interview towards employees’ issues, habits and observations. As the interviews advance, new questions are added to the interview according to employees’ responses. For

example, after first couple of interviews, all employees' stated that they are wearing earphones. From that point on, questions about earphone usage have become part of the core questions.

Interviews are concluded once the collected data no longer produced significant conceptual variations (Corbin & Strauss, 1998; Dey, 1999). Interview process lasted for 2 work days for both offices while they are fully occupied. Interviews are held at meeting rooms and their duration varied between 6-17 minutes. All interviews are recorded and transcribed. Transcriptions are manually coded to derive themes and categories, which are used to create a conceptual framework that reflects employees' perception of the soundscape of their work environment and the factors that are affecting it.

#### **3.2.4. PANAS (Positive and Negative Affect Schedule)**

As it was stated previously, PANAS test is used to measure employees' mood. This test consists of twenty emotions, half of them are associated with positive affect while or half is associated with negative. These emotions are placed in random order to avoid participants from recognising the positive or negative aspect of the emotion. Participants are required to rate each emotion from a 5 point Likert scale, 5 representing very much and 1 representing very slightly (Appendix Figure B 1).

After each interview, employees' are given PANAS form to fill. PANAS questionnaire includes both English and Turkish versions of each emotion.

In order to evaluate the PANAS forms, each set of emotions (Positive and Negative) are calculated separately. Calculation of these two set of emotions provide two scores; the *Positive Affect Score* and the *Negative Affect Score*. Both scores are range from 10 - 50. Higher score of positive affect represent higher levels of positive affect, while higher scores of negative affect represent lower levels of negative affect. Responses gathered from the PANAS test are used to explore relations between employees' mood, satisfaction with the overall sound levels and objective parameters of their office environment.

## **CHAPTER 4**

### **RESULTS**

This chapter will present the findings of objective parameters and subjective surveys. From this point on, abbreviations will be used instead of the full names of companies to make it straight forward. As Öncüoğlu + ACP Architects is an architecture company it will be referred to as Office ARCH. Similarly, as the Promer Engineering Consultancy is concerned with engineering its abbreviation will be Office ENG.

#### **4.1. Objective Results**

##### **4.1.1. Equivalently Continuous A-Weighting Sound Levels (LAeq) and Reverberation Time (T 30)**

There is a slight difference between offices in terms of Equivalently Continuous A Weighted Sound Levels (LAeq). Measurements showed that Office ARCH has 55,3 dB(A) mean LAeq, while Office ENG has 59,4 dB(A). Difference between the

measurements are not surprising, due to the fact, in Office ENG, there are more people working in a smaller office space when compared to Office ARCH.

Reverberation time (RT 30) is simulated for all frequencies with the simulation prepared by the ODEON Room Acoustics Software 13.01 Combined (Figure 14).

However, the literature, and the subjective survey of this thesis shows that speech is the most common sound in open plan office. Therefore, only the common frequencies of speech are considered to be significant, which are 500Hz, 1000 Hz, and 2000Hz. For the simulation, the background noise is considered to be 55 dD (NC 55).

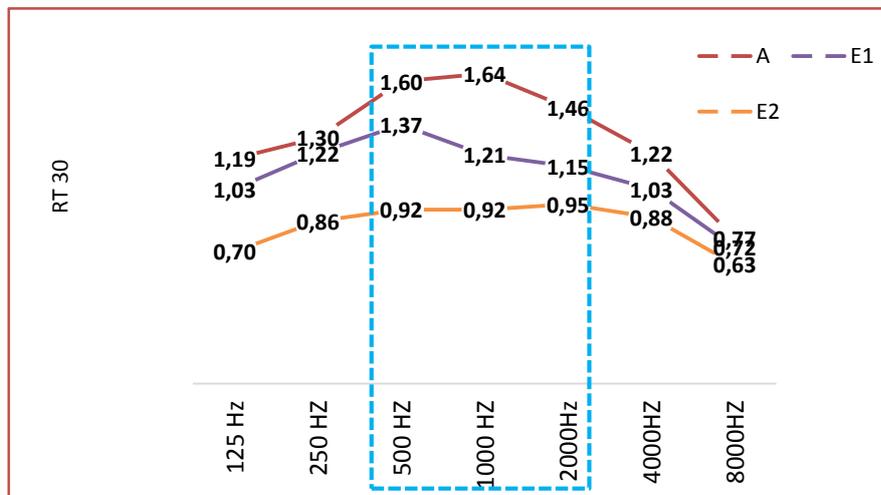


Figure 13: Reverberation times for all central frequencies. The dashed rectangle indicates the common speech frequencies.

As it was previously mentioned in the section “Case Study Settings”, open office space of Office ENG is composed of a main office space and a subspace. The model that is prepared for Office ENG simulation is also divided into two separate parts to

get accurate results from the simulation. In order to make it easier to address these spaces, the main space will be referred to as Office ENG1, and subspace will be referred to as Office ENG2.

It can be seen from the Figure 14, that reverberation time, between the frequencies of 500Hz to 2000Hz, for Office ENG1 varies between 1,37 to 1,15 and for Office ENG2 it is between 0,92 to 0,95. For Company ARCH, reverberation time between 500HZ to 2000HZ varies between minimum 1.43 and maximum 1.61, which is a more appropriate reverberation time for an auditorium (Figure 2). The more detailed distribution graphs can be seen between Appendix Figure A3 to Appendix Figure A8.

#### **4.1.2. Speech Transmission Index (STI)**

Simulation prepared at Odeon Room Acoustics Software provided the distribution of STI values for both offices (Figure 15&16) (Appendix Figure A9 to Appendix Figure A11). According to the distribution graph, mean STI value is around 0.52 which stands for *Fair* amount of STI (Figure 3). The mean STI value of Office ENG1 is 0.56 which is quite similar with Office ARCH, Office ENG2 has slightly higher mean value of 0.63, which means *Good* intelligibility of speech (Figure 3).

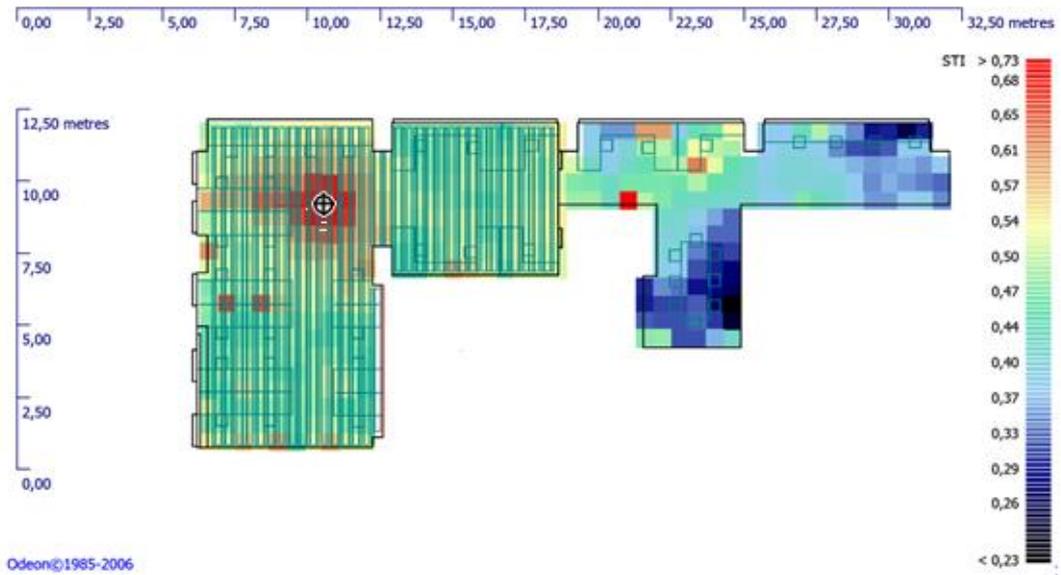


Figure 14: STI Grid response of open plan office of Öncüoğlu + ACP Architects (Office ARCH). Black mark indicates the location of the sound source.

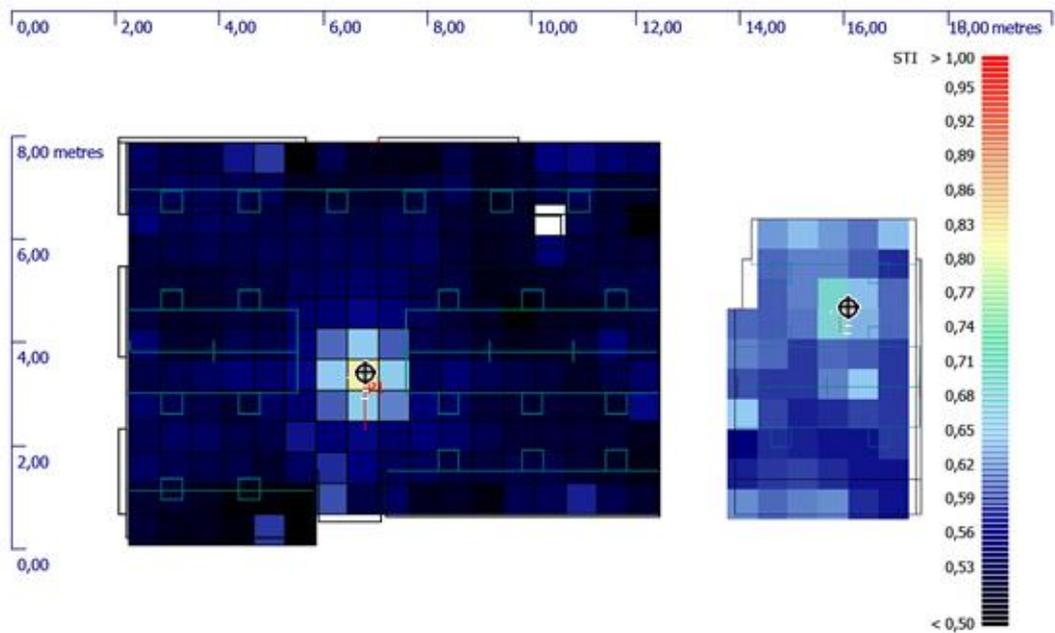


Figure 15: STI grid response of open plan office of Promer Engineering Consultancy (Office ENG). The plan on the right belongs to the main office space (Office ENG1) and the left one belongs to the subspace of office (Office ENG2). Black marks indicate the location of sound sources.

These results show that both of the offices have STI ratings, which are slightly higher than those suggested by the literature and ISO standard (ISO, 2012). To avoid a decrease in task performance due to speech, the STI value should have been higher than 0.50 and to provide sufficient amount of speech privacy it should be higher than 0.20. In order to see if the objective parameters of ODEON simulation apply to the actual perception, employees' responses to the interview will be taken in account in following chapter, "Discussion".

#### **4.1. Subjective Results**

Analysis of the semi-structured interviews began with transcribing all recordings. Once all recordings are transcribed, coding procedure started with open coding. This process can be described as breaking down interview transcriptions into pieces by labelling each significant event (Figure 17). In order to do this properly, researcher has to be familiar with the data. To ensure this, all interviews, transcriptions and coding is done by the author, and portion of the open coding documents are checked by a professor from faculty.

As it can be seen at Figure 17, employees' responses are broken down to pieces by labelling each significant event. For the second phase, the axial coding, these labels are searched for relationship patterns, and put together in accordance with their

relation. For example, sound of keyboard is labelled as “SS (MECH1)” and the sound of employees engaging in a group conversation is labelled as “SS (HMN)”. After this point, *keyboard*, becomes a sub category of “SS (MECH1)”, which has now also becomes a main category, and *group conversation* becomes a sub category of “SS (HMN)”. Now that we have two main categories author looks for relation between them. As both of them are sound sources, together they create a theme, called “Sound Sources”. Using the constant the comparative method, all labels that show any patterns with one another are used to form themes. Labels which do not have any relation with others are eliminated during this process.

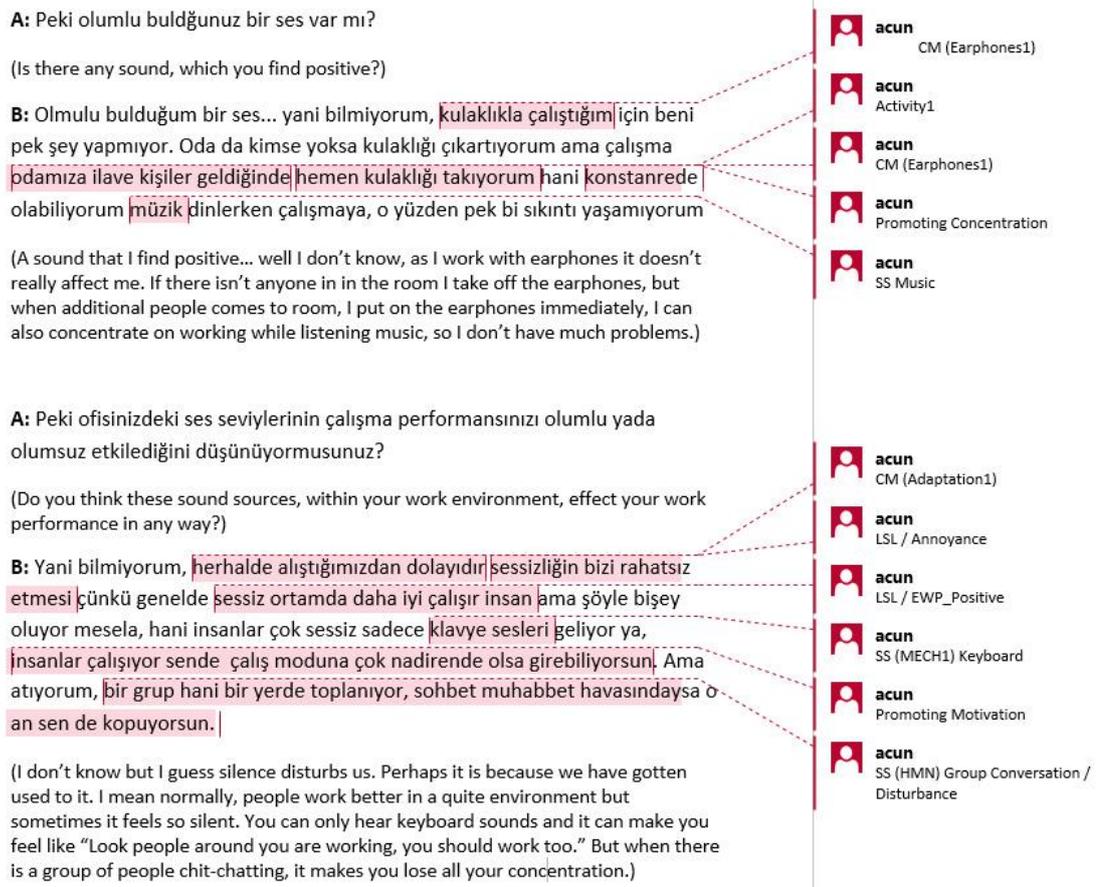


Figure 16: A sample taken from the transcriptions, which shows how data is broken down into labels during open coding. Abbreviations: CM= Coping Method, LSL= Low Sound Levels, EWP= Effecting Work Performance, SS(HMN)= Sound Source Human SS(MECH)= Sound Source Mechanical & Electronical

Last phase of coding is Selective Coding. As the axial coding has put the data back together and provided us with themes, the main theme had to be identified and find how other themes relate to one another, and to the main theme. As the main goal of this research is to explore employees' perception, main theme is selected as Perception of Soundscape, which is also pointed out by the data. Based on these patterns conceptual model is created, which is used to understand employees' perception of his workspace.

Study aimed to compare two open offices spaces and construct a conceptual model for each one of them as they were expected to be different from each other.

However, analyses of the data showed identical patterns and categories for both of the offices. Therefore one conceptual model is generated for both cases (Figure 18).

This analysis of data revealed 10 themes which are divided into 29 categories (Appendix Table B 2).

Conceptual framework showed some similarities between the one prepared by Mackrill *et al.* (2013), which is a soundscape research conducted in a hospital ward.

Similar to this research, there are some intervening conditions that acts like a filter and directly effects employees' perception of their work environment. These

intervening conditions consist of 5 themes; Environmental Factors, Temporal Factors, Employee Characteristics, Work Type and, Physical Properties of Space.

Categories of these can be seen at Figure 18. When the sound source, of a certain

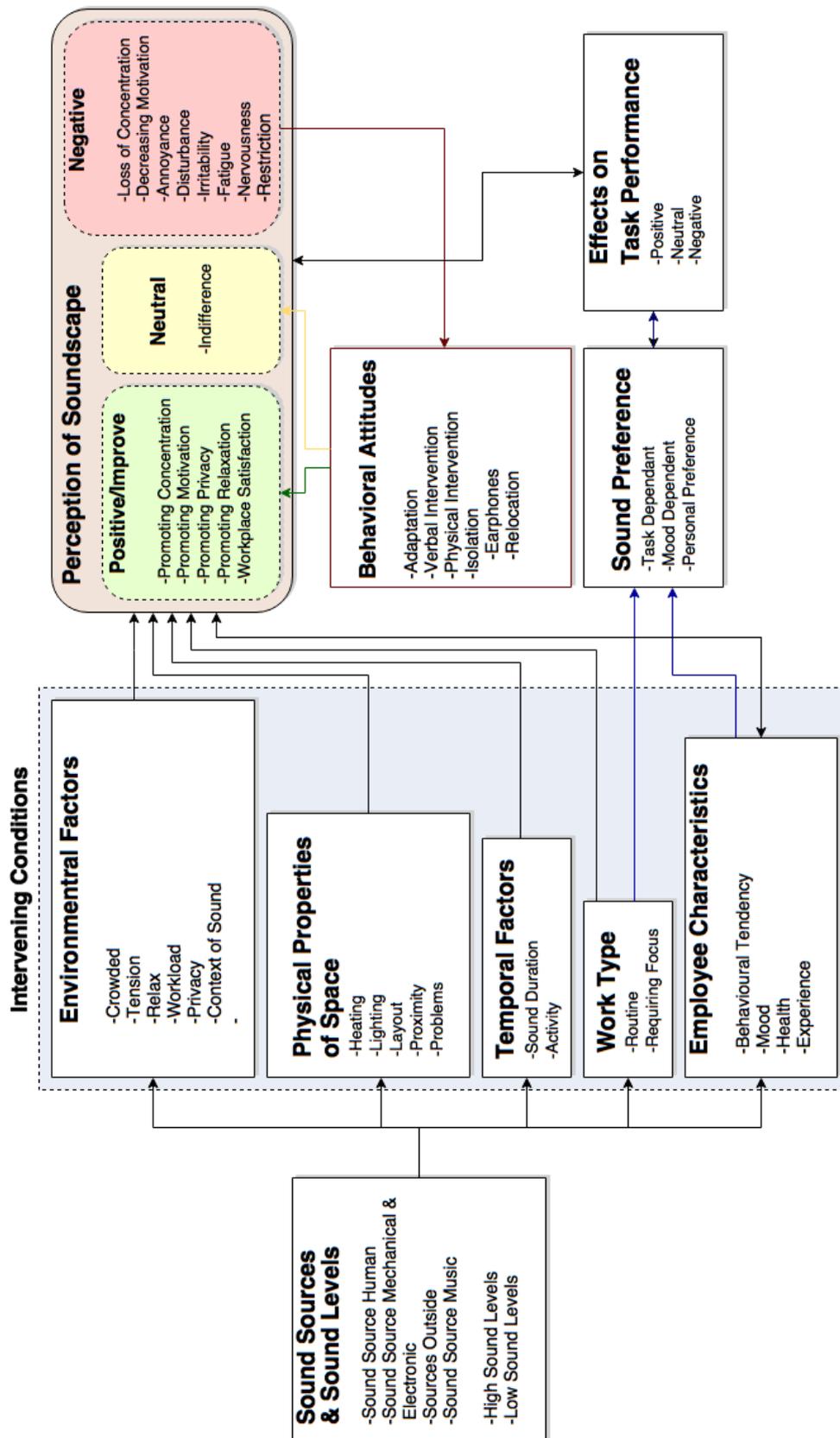


Figure 17: Conceptual Framework prepared by the author, which shows the categories, main themes and the patterns between them

level, is heard these conditions intervene between hearing and perception.

Therefore, perception of sound is directly linked to the intervening conditions.

It has been found that, sound preference, and sounds effect on task performance are directly or indirectly associated with intervening conditions and perception of sound. Sound preference is directly associated with Employee Characteristics and Work type. During the interviews it has been stated numerous times that sound preference changes according the task that is being performed. Employee characteristic effects sound preference depending on the mood and personal preference.

After the sound is heard by individual, employees' make a judgement of that sound based on intervening conditions, and its effect on the task they are performing, thus, creating a perception of that sound source. This perception can be positive, negative, or neutral. Themes derived from the interviews also shows, what causes a certain type of perception, and what does it lead to. If the perception of the sonic environment is negative, employees' can either accept this, or develop some coping methods, similarly to the research of Mackrill *et al.* If the employee accepts this negative perception, it will result in maintaining a state of annoyance, fatigue, restriction, etc. Interviews showed that these coping methods consist of three main categories; adapting to the sonic environment, isolating from the environment by relocation or putting on earphones, and making a verbal or physical intervention

to the sound source. Developing a coping method can lead to a positive perception of the soundscape by promoting individuals current state.

As it was stated previously, identification and description of sound sources in a particular place gives valuable information about the soundscape of that place because sound sources can be perceived differently from place to place. During the interviews, employees' are asked to list the sounds they hear. Their responses are used to create a table that shows lists sound sources and frequency of mention by employees (Table 1).

Table 2: List of sound sources which shows the frequency of mention by the employees

OFFICE ARCH Sound Sources				OFFICE ENG Sound Sources			
<b>Human Generated Sounds:</b>	<b>87</b>	<b>Mechanical &amp; Electronical Sounds</b>	<b>53</b>	<b>Human Generated Sounds:</b>	<b>106</b>	<b>Mechanical &amp; Electronical Sounds</b>	<b>58</b>
Speech	57	Keyboard & Mouse	13	Speech	50	Keyboard & Mouse	15
Group Conversation	4	Printer/Plotter	16	Group Conversation	16	Printer/Plotter	13
Phone Conversation	18	Computer Fan	10	Phone Conversation	5	Computer Fan	6
Rattling Noise	1	Air Condition	4	Rattling Noise	6	Telephone	16
Footsteps	6	Telephone	7	Footsteps	11	General	8
Laughing	1	General	3	General	18		
<b>Sound Source Music:</b>	<b>30</b>	<b>Outside Sounds:</b>	<b>18</b>	<b>Sound Source Music:</b>	<b>44</b>	<b>Outside Sounds:</b>	<b>18</b>
		Nature	5			Nature	3
		Animal	11			Animal	8
		Traffic	2			Traffic	2
Total = 188				Total =226		General	5

#### 4.1.1. Soundmarks

In order to see if the soundmarks of outdoor soundscape also apply to indoor, employees are asked “Do you associate any sound with your work environment?” Their responses can be seen at the figure below (Figure 19 & 20). Overall results show that majority of employees’ do not associate any sound with their workspace.

However, if we approach the offices separately, Figure 19 shows that more than half of the employees’ in Office ARCH associate their workplace with some sort of sound source (n=14). On contrary, Figure 20 suggests that not only vast majority of employees’ does not associate any sound with their workspace but also, the possible soundmarks suggested by the employees’ consists of different sound sources with very low frequency of mention.

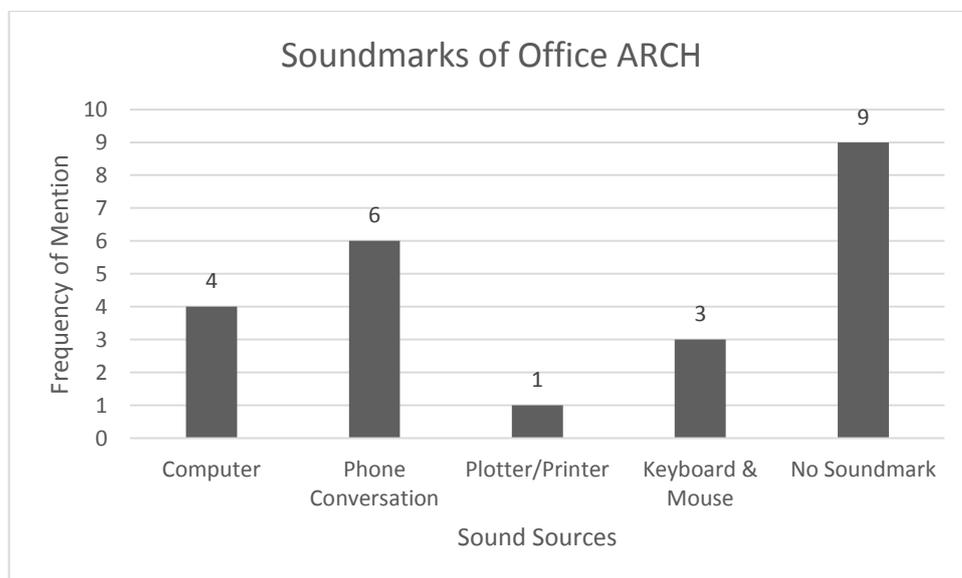


Figure 18: Sound marks mentioned by employees of Office ARCH

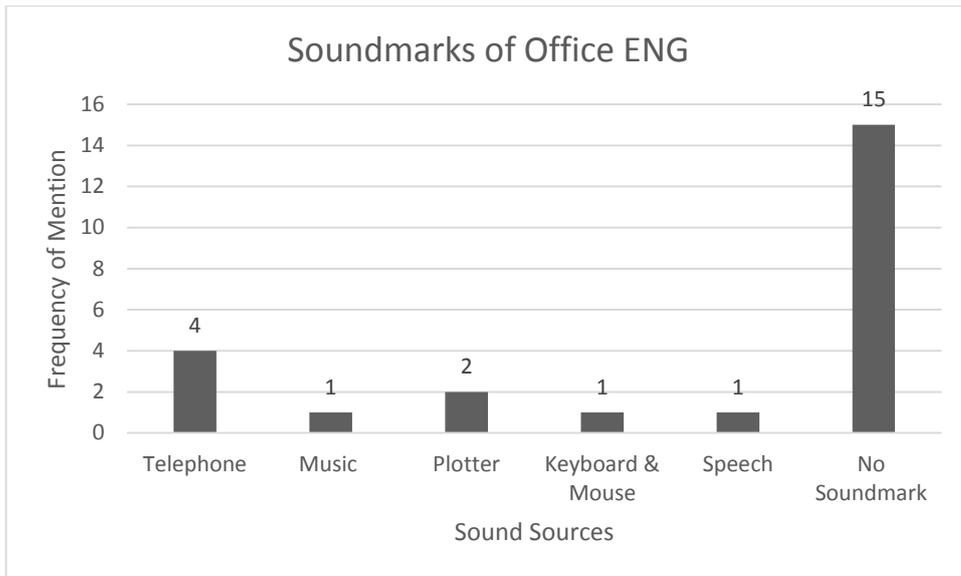


Figure 19: Soundmarks mentioned by the employees of Office ENG

#### 4.2. Results of PANAS Test

During the interviews employees' are asked, if they are satisfied with the soundscape of their work environment. In the context of this thesis, satisfaction is defined as the fulfilment of ones wishes, expectations, or needs, or the pleasure derived from this. Their answers are based on a Likert scale of 1-3, with 1 meaning not satisfied and 3 meaning satisfied (Appendix Figure B 2). Employees' levels of satisfaction with the overall sound levels is correlated with their responses to the PANAS.

PANAS scores for PA (Positive Affect) and NA (Negative Affect) can be seen at Appendix Figure B3. Results showed that 64.44 % of the employees' have "Moderate to High PA", which corresponds to a PA score between 30 and 40. On the other hand, 62.79 % of the employees' have "Low NA" which corresponds to NA

score between 10 and 20. It should be noted that this is the lowest score range for NA. Therefore, it can be said that majority of the employees have positive affection.

The main aim of correlating satisfaction and PANAS is to see if employees' satisfaction with overall sound level within the work environment effects their mood. In order to explore this association correlation test is conducted using IBM SPSS Statistics 21. For this correlation, satisfaction is identified as the independent variable and its scale of measurement is identified as Ordinal. On the other hand, PANAS scores are identified as the dependant variable with interval/ratio, scale of measurement.

To correlate ordinal data with interval/ratio data, *Spearman's rho* ( $r_s$ ) is chosen, as it requires at least one variable to be ordinal (Argyrous, 2011). Spearman's rho provides values between -1 to 1. In this scale, scores closeness to -1 or 1 indicate the strength of relationship with 0 meaning no association at all. The negativity or positivity of the score indicts the direction of association (Argyrous, 2011).

During the analysis of PANAS questionnaires, 2 of them eliminated, as participants did not fill the questionnaires correctly, which makes the total sample size 45.

Statistical results showed moderate positive association ( $r_s = 0.559$ ,  $n=45$ ) between employees' satisfaction of overall sound levels and positive which means, as the employees' satisfaction increases positive affect also increases (Table 2). In other words, satisfied employees' have more positive mood. On the other hand,

moderate negative association ( $r_s = -0.456$ ,  $n = 45$ ) is observed between satisfaction and negative affect, which can be interpreted as the employees' satisfaction decreases, negative affect also decrease.

Table 3: IBM SPSS 21 output of the spearman's rho correlation test.

		Employees' Satisfaction of the soundscape	Positive Affect	Negative Affect
Employees' Satisfaction of the sonic environment	Correlation Coefficient	1,000	,559*	-,456*
	Sig. (2-tailed)	.	,000	,002
	N	45	45	45

According to these results there is at least a moderate association between satisfaction employees' satisfaction with the overall sound levels and their mood. As employees' satisfaction increases this affects their mood positively, they obtain a pleasant, alert and active feeling state. On contrary, when they are not satisfied with the overall sound levels, their mood is affected negative as they now have an unpleasant engagement.

Results of the objective parameters has shown that offices have similar acoustical characteristics in terms of STI and overall noise levels. However, in terms of reverberation time (T 30) they are quite different. It can be seen from Figure 14 that there are around 0.30 second difference between Office ARCH and Office ENG in all central frequency bands between 500 Hz to 2000Hz. Considering that other

objective parameters are quite similar, this finding, along with the results of PANAS raised a question. Does the difference between the reverberation times has any effect on employees' mood? In order to explore this, independent samples T-test is used to compare the means of PA and NA.

Table 4: Output of the independent samples T-Test, conducted using IBM SPSS 21.

Group Statistics					
Reverberation time of offices		N	Mean	Std. Deviation	Std. Error Mean
Positive Affect	Office ARCH	24	36,33	5,272	1,076
	Office ENG	21	35,38	3,918	,855
Negative Affect	Office ARCH	24	19,75	7,415	1,514
	Office ENG	21	20,95	10,244	2,236

Independent Samples Test					
		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Positive Affect	Equal variances assumed	1,697	,200	,679	43
	Equal variances not assumed			,693	41,967
Negative Affect	Equal variances assumed	1,380	,247	-,455	43
	Equal variances not assumed			-,445	35,966

Independent Samples Test					
		t-test for Equality of Means			
		Sig. (2-tailed)	Mean Difference	Std. Error Difference	
Positive Affect	Equal variances assumed	,501	,952	1,402	
	Equal variances not assumed	,492	,952	1,374	
Negative Affect	Equal variances assumed	,651	-1,202	2,643	
	Equal variances not assumed	,659	-1,202	2,700	

Results from a sample of 24 employees from Office ENG and 21 employee from Office ENG suggests that the difference in reverberation time does not affect employees' mood (Appendix Table B 5). According to the result of T-test, the difference between Office ARCH and Office ENG, in terms of PA, is not statistically significant at 0.05 level ( $t=0.679$ ,  $df= 43$ ,  $p>0.05$ ). Similarly there aren't any statistically significant difference between Office ARCH and Office ENG in terms of NA at 0.05 level ( $t=-0.455$ ,  $df=43$ ,  $p>0.05$ ).

## **CHAPTER 5**

### **DISCUSSION**

The hypothesis of this research is, indoor soundscape perception effects employees' perception, and mood. To further understand this phenomenon, semi-structured interviews are conducted with employees to derive themes and categories, in the end which turns into a conceptual model that shows employees' perception of their workplace soundscape and all the factors that affect the process. PANAS test is conducted to see if there is any relation between employees' satisfaction with the soundscape and mood. In order to see if the objective parameter of Reverberation Time has any effect on mood, independent samples T-Test is used to compare the offices. This chapter will focus on discussing these results while focusing on, significant findings, the expected results, their relation with the literature and contradictions.

In the following section, each part of conceptual model will be discussed and explained, starting from the sound sources and sound levels. In order to provide in-depth information of employees' perception, direct quotations will be used when necessary. Some of these quotations are also used before in Acun & Yilmazer's

(2015) proceeding of EURONOISE 2015. As all interviews are held in Turkish, following quotations are translated to English.

### **5.1. Auditory Perception of Soundscape**

Perception is defined as, understanding and representing the sensory environment through organization, identification and interpretation (Schacter, 2011). In order to explore employees' perception of the soundscape of their office environment, the sound sources, which contribute to the soundscape, needs to be identified. Brown *et al.*, (2011) also stated that identification of sound sources are an essential part of soundscape studies. Interviews are started with asking employees' what they expect to hear, what they actually hear, and what would they prefer to hear. Deductions made during participants responses to these questions helped to develop new question which provided valuable information about their perception.

Just like the previous researches have shown, speech is the most commonly expected, and heard sound within the work environment. Even though some of them disagreed, mechanical and electronic sounds such as printers are second most expected sounds.

***E (Employee):*** *I don't know what the ideal is but I think I expect to hear human dialogue, which is the ideal sound for me, not a printer sound.*

As it is stated by Truax (2001) and later supported by Bruce *et al.* (2014), soundscape competence is a tacit knowledge, employees' expectations from the soundscape is mostly based on their previous experiences. Expectation can affect employees' perception and behaviour greatly. Hearing sounds of printers, computers and people typing mails is something that was anticipated. However an interesting finding is that sound of keyboards, is actually perceived positively by a substantial amount of employees, (n=33) while no one mentioned that sound of a printer or sound of a computer is positive. Employees expressed that the sound of keyboard and mouse means that they are working at that moment, there are other people around, and they are not working alone, or working overtime. An employee even stated that it motivates her.

*E: Well as for the positive ones, keyboard sound doesn't affect me negatively. It shows that there is work. Sometimes when I slow down it even motivates me.*

These findings directly point out the importance of the context as it was suggested by the literature (Schafer, 1977; Truax, 2001; Brown *et al.*, 2011; Bruce *et al.*, 2014). Normally the sound of a keyboard or a mouse is the indicator of the company's business. It means that the individual is not alone within the office, company is in good shape because there are tasks people are attending to. This, in a way, motivates people, encourages them to work by making them think "*People around you are working you should do the same*" as quoted by an employee. This sound source is perceived as positive, or neutral, by the employees most of the time. However, as the context of sound is altered by emotions, the perception can become negative.

Responses of 5 employees revealed that there is an underlying theme beneath this perception such as the mood and emotions that is associated with the act. These employees reflected that they are in fact annoyed by the sound of keyboard but not because it disturbs them it is due to the information that is provided to the listener about his co-workers and how it affects the listener. For example:

*E: The colleague working next to me uses the keyboard very roughly. Sometimes he types like he is bashing the keyboard which disturbs me a lot.*

*E: When someone is typing an angry email or trying to rush a job, they type really really hard which breaks all my concentration.*

Proximity to the circulation routes, and main gathering spaces is also a significant factor. As it was stated previously, the office space of Office ARCH has two different ceiling levels, because of this, the main meeting room located at the second floor has glass covered opening, that are directly facing the office space. During the interviews in Office ARCH, 5 employees that are seated near this meeting room said they can hear all meeting loud and clear while others didn't have any idea about it.

As they can understand almost everything, these employees' expressed annoyance, disturbance and loss of concentration due to this. The STI grid response of this area shows that STI ratings are around 0.50 (Figure 21). This is the point where negative effect on task performance starts to decrease. Deductions can also be made from

employees' subjective perception that this location has problems with speech interference. Based on these responses, and measurements it can be said that results are consistent with literature. However, in order to get solid values, radius of distraction ( $r_D$ ) and radius of privacy ( $r_P$ ) can be calculated based on the prediction model of Hongisto (2005).

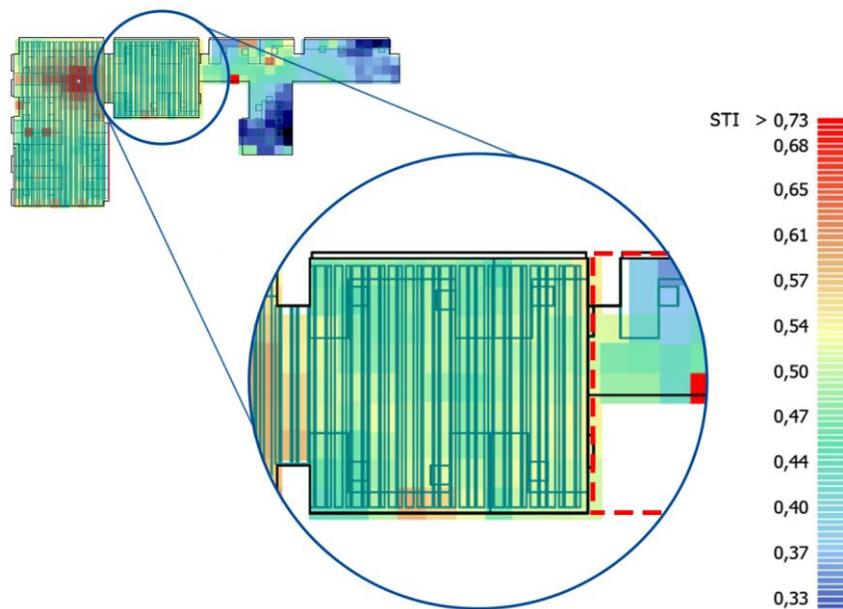


Figure 20: STI grid response of the workstations that are located near the meeting room at upper floor. The red dash line is the projection of the meeting room of upper floor.

Proximity to the printer also shows same patterns with meeting room. But in this case employees around it are adapted to its sound and some of them even associated it with their office, which is very similar to Schafer's soundmarks.

*E: As the printer is right around the corner, in my mind its sound is associated with office. When I don't hear it, I wonder if it's broken or something.*

It can be seen from these examples that, when sound is heard by the listener, they search for pieces of information within it. Environmental factors, such as the

tension within the environment or workload, coupled with employee characteristics like “*the keyboard basher’s*” mood, leads to a negative perception of that particular sound as it makes the listener lose his concentration or affect his mood.

#### **5.1.1. What do they prefer to hear?**

When they are asked “what do you prefer to hear?” almost all of the employees, from both offices, responded music. However, using music as source of background sound has its problems. During the interviews in Office ARCH, it has been learned that there used to be a music broadcast. Years ago, when company was located elsewhere, management thought that it would be nice to have a music broadcast and prepared playlists of their choice. After sometime they had to cancel it because not everybody liked the same genre and people got fed up with hearing music all the time. In their current office, there is no music broadcast. So it can be said that employees preferred to hear music in theory but not in practice.

*E: I would prefer music but I don’t know if it would work. I think it’s really hard to implement because **it’s very hard for people to find a common ground.***

Same thing can also be said about Company E where they currently have a central music broadcast in every room. The broadcast system is different for each office space. It can be controlled from a panel and it consists of one playlist. However, during two days of interviews, there wasn't any broadcast at all. Employees' preferred to listen the music through their earphones, and rarely, they turned it on during lunch breaks. When they are asked if they want to be the one that is in charge of selecting the music one of the employees rejected it by saying:

*E: No I would never want that, I think it is not possible to satisfy everyone. It is better if everyone listens their own music.*

Reponses indicate that the main reason why people don't want music broadcast is because it is very hard to find a music genre that everybody would appreciate, even impossible. It is also related with the fact that even if they like what is playing, it might not always be suitable while working as it can interfere with work and result in a loss of concentration. Employees say that genre of the music is very important; if it is something they don't like music becomes a major negative sound source.

*E: Playing music is very important, **if it's something I don't like, it's better to have music at all.***

Table 2 shows music as the third frequently mentioned sound source. What this really stands for, is the music they listen through their earphones. So, "I prefer to

hear music” actually means is, *“I want to hear the music of my choice”*. Other than two employees in Office ARCH and 1 employee in Office ENG, all of the employees use earphones to listen whatever they want. Responses indicate that this is not just out of the desire to listen music. It has become a coping method. It is a method of creating their own auditory environment when the present one is no longer satisfactory. Following up on the example given before; environmental factors of tension, workload coupled with mood and proximity to a loud meeting room leads to a negative perception. At his point our employee is not satisfied with this work environment due to decreased motivation, fatigue and such. He has to cope with this somehow and simplest way to do so, is to put on earphones and find something that he likes. Responses indicate that by doing so, employee’s perception becomes more positive. The question is, whether his perception the office soundscape that is improving or the one he created for himself? The former one seems highly unlikely.

Using earphones also gives employees the option to change the music if they don’t see it fit, which is not possible with a broadcast system. It has been stated by every single employee that their music preference change depending on the task they are performing. It has been seen that employees tends to react more positively towards semantic sound sources, such as music and speech, when they are performing visual based tasks and relatively more straightforward tasks, such as modelling or adapting changes from one plan to another. On contrary, while performing more semantic tasks, such as writing a report, they tend to develop a negative perception towards nearly all kinds of sound sources and preferred absence of sound.

*E: If I am checking something I can use a little music, but if I am performing a visually based modelling, I can listen to music in background... **but of course you cannot listen to music while writing something.** You need to write report and focus on it. The words you hear can switch with the words you type.*

*E: While reading an article, I prefer to listen types of **music that has as few lyrics as possible or classical music.** Songs with low beats and low accents can be nice also. But there is no problem on tasks like modelling, which you can proceed straightforwardly.*

Another finding of the research is, other than some employee's behavioural tendency, large amount of employees' are uncomfortable with low sound levels as much as they are with the high sound levels. When there is a lack of background sound, employees expressed concern about these silent periods, which can also indicate problems with speech privacy. Office ARCH has STI rating of 0.52 while Office ENG1 and E2 has ratings of 0.56 and 0.62 respectively. According to the literature, these STI ratings are not suitable for speech privacy nor for task performance (Hongisto, 2004; Kitapci, 2008). Intelligible speech, in an open office space, means that everyone relatively close to the speaker can listen to the conversation, thus, reducing the speech privacy. Also, employees' in close proximity can involuntarily hear the conversation and can suffer from interference-by-process type of auditory distraction (Kim and de Dear, 2013). However, during the interviews employees mentioned about their privacy concerns very few times. During the interviews it has been seen that, their privacy concerns mostly consists of private phone calls. In Office ARCH, they came up with a method going outside the Office and answering them. A coping method of isolation and relocation. Other

than the private phone calls, employees aren't very concerned about privacy of their conversations.

In Office ENG, however, there is a special room meant for phone calls. The important point here is, in Company A, employees developed the method of making private phone calls at outside. For Office ENG, it is a company rule to make every single private phone call at the telephone room and they express discomfort about it (n=7/25). On the other hand, only 2 employees, from Office ARCH expressed discomfort. They did not express need of a telephone room also. It should also be noted that when Company E dictates a special place to talk to phone, it is received more negatively than the actual problem of privacy. Responses imply that people like to know that they have the freedom of answering their phones in their workstations regardless of speech privacy even if they won't do it.

It has also been observed that, the problem associated with low sound levels and speech intelligibility is the fear of effecting others task. It has been mentioned by employees of both companies that they tend to reduce their voices in order to avoid disturbing others most of the time. They restrict themselves from making any sudden sounds or loud conversations. When this restriction is performed for a whole day it leads to fatigue which effects the perception of soundscape negatively.

### **5.1.2. Outdoor Sounds**

During the interviews in Office ARCH, employees' responses showed some interesting findings about how outdoor audio-visual elements effect the perception and mood of employees. Office ARCH is actually located in a very central location, right next to the main routes of transportation, it is within a private residential block. It is completely isolated from its surroundings which is the reason why outside sound sources are mentioned so few times. However, there is one sound source that is mentioned by the majority of employees, which is the sound of ducks and geoses that lives within the garden of the office.

It can be stated that no one has a complaint about them. Located in outdoors, they are actually effecting indoors positively. This positive effect is not only limited to the auditory environment. Their main positive effect is their visual appeal. It is almost like hearing those sound, makes employees visualise them. This resembles Truax's acoustical communication theory. Perception of the sound provides information about the sound source which actually creates a mental image of it. As it is expected employees, such as the accountants, that are seated in a different office, envy architects and their studio because their view consists of a retaining wall.

### 5.1.3. Soundmarks and Keynote Sounds

Some interesting findings are observed during the analysis of employees' responses to the question "Do you associate any sound with your current work environment?". Some employees associated, computer fan and printer/plotter with their workspace, thus making them possible soundmarks. However, sound of a computer fan can also be classified as a keynote rather than a soundmark. Unless it is a very silent environment, sounds coming from a computer fan is more like a keynote, a ground which the figure (signal sound) is placed upon.

Another possible soundmark, which could actually be a keynote is the sound of printer/plotter. These sound sources are perceived negatively by vast majority of employees and associated with workspace 3 times (Figures 18 & 19). However what makes it interesting is that one of those employees' who associated it with the workspace, said:

*E: As the printer is right around the corner, in my mind its sound is associated with office. When I don't hear it, I wonder if it's broken or something.*

In his seminal work "The Soundscape: Our Sonic Environment and the Tuning of the World", Schafer suggests that:

*"Keynote sounds are, however, noticed when they change, when they disappear altogether, they may even be remembered with affection (Schafer, 1977)."*

Judging from Schafer's description, it can be said that this employee is actually referring to a keynote. Based on this, it is curious how many other employees answered this question about soundmark while actually referring to something else.

In order to make proper assessment of typology of sounds, a more detailed study, which focuses only on this topic, should be conducted. A research can this may lead to design considerations or perhaps more passive ways to improve indoor soundscape quality.

A future study focusing on identification of sound sources and typology of sounds can also show if there are Hi-Fi and Lo-Fi indoor soundscapes. As both of these are associated with ambient noise, different indoor spaces may require different type of soundscape. While a concert hall requires an acoustical environment suitable to hear all frequencies clearly (like a Hi-Fi soundscape), an environment where some frequencies are masked, can be more suitable for an open office space (Lo-Fi soundscape). While there are mostly just assumptions, as there isn't any research focusing on this aspect, future study can contribute to design decisions.

## **5.2. Employees' Mood**

The PANAS results showed that there is a positive moderate association between soundscape and positive affect and negative moderate association between satisfaction with soundscape and negative affect. This can be summarised as; if they are satisfied with the soundscape it can affect their mood positive but if they are not satisfied it can affect negatively. During the interviews it is also expressed that employees' mood also affects their perception and task performance.

The result of the independent samples T-Test, which is conducted to see if reverberation time affects employees' mood, showed no significant difference between offices in terms of PA and NA, thus, stating that reverberation time does not affect mood. Considering that among all objective parameters, reverberation time is the only parameters that changes significantly (STI values are 0.52 for Office ARCH, 0.56 for Office ENG1 and 0.62 for ENG2 and overall sound levels ( 55.3 dB(A) for Office ARCH, 59.5 for Office ENG), it can be clearly said that none of them affect mood. For future studies, researchers can look at different parameters such as *definition* (d50) or spatial decay.

Another option for future studies can be to use the conceptual framework provided by this thesis. It suggests that there are various factors affecting employees' perception of their sonic environment and mood appears to be one of these. Spearman's rho test already showed that there is a moderate association between satisfaction and sound levels. Similarly, the conceptual framework can be used to seek associations between mood and various themes/categories.

On the other hand, the PANAS test conducted for this research has a limitation, there are too many uncontrolled variables. PANAS test is conducted in an uncontrolled environment with various interfering. Employees' workload, their relations with their co-workers or with their boss are some of the factors that can affect their response to the PANAS questionnaire. In order to avoid this, a controlled environment has to be created with soundscape being the only

significant variable. Kwallek et al., (1996) created 3 different office set ups to study impact of three different colour schemes towards employees' mood and performance. A similar environment can be created to conduct a detailed research specifically about mood and soundscape.

## **CHAPTER 6**

### **CONCLUSION**

Aim of this study is to explore the effects of indoor soundscape quality towards employees' mood, task performance and perception of their work environment. Due to the lack of case studies regarding indoor soundscape quality, two open plan offices are chosen for the research. Within the context of this research, grounded theory, measurement of objective parameters, and mood tests are used. Semi-structured interviews are conducted with 49 employees, as part of grounded theory. Their responses are used to create conceptual framework that shows employees perception of the soundscape. Objective parameters and mood tests are used to compare and discuss this model.

The sound sources, which compose the soundscape of open plan office space, environmental factors that contribute to the perception of this soundscape is identified by through semi-structured interviews. Based on these, a conceptual framework is created which reflects the lived-in experience of an open plan Office and confirmed that the soundscape quality of a certain space cannot be evaluated

by objective measurements alone. Conceptual framework helped to visualize the perception process of the soundscape. It showed the significant factors that contribute to the perception and links between a certain type of perception and environmental factors. Among all these, mood is one of the most reoccurring factor and it is confirmed by the PANAS test that there is a moderate positive association between satisfaction with the sound levels and positive affect, and moderate negative association between satisfaction with the sound levels and negative affect. This suggests that if employees are satisfied with the sound levels, their mood is affected positively. On contrary, if the sound levels are somehow disturbing, their mood is affected negatively.

Comparison of reverberation times based on PA and NA scores, using independent samples T-test, showed no statistically significant difference between offices. This result can be interpreted as reverberation time does not affect mood in open planed offices.

Correlations conducted between satisfaction and PANAS scores showed that there is at least a moderate association between them. Observations and responses during the semi-structured interviews suggests that mood has a significant effect on employees' perception of the soundscape. It can directly affect the perception of a certain sound source and same way a certain sound source can directly affect mood, workplace satisfaction, task performance. A more detailed, user focused

research, designed to incorporate statistical analysis can be used to develop a board understanding.

The research did not identify any significant soundmark, however, it has been seen that one simple question can be lead to asking more questions. A future study designed to investigate the typology of indoor sounds can provide important finding and reveal similarities/differences between indoor and outdoor soundscapes.

Even though, employees' did not express any significant issues about speech privacy, STI ratings provided by the ODEON simulation shows that intelligibility of speech is defiantly too high to promote speech privacy. When compared with the literature, STI ratings in both offices indicate that speech intelligibility can cause a decrease in performance and speech privacy issues. Employees' responses are consistent the objective parameters as they expressed, a loss of concentration, decrease in motivation, annoyance and disturbance due to the soundscape (Table 1), yet, measurement of other parameters such as *Definition* (D50) can be helpful to develop better understanding in further studies. This negative perception of soundscape results in some coping methods based on behavioural attitudes (Figure 18). Some employees can adapt to this negative perception while other tend to isolate themselves or try to intervene the cause of this. On the other hand, positive perception of the soundscape can promote concentration, motivation and workplace satisfaction (Figure 18).

This study provides a better understanding about why and when a certain state of perception occurs, by giving an insight from employees' account. This study is concerned with contributing to the soundscape theory. Due to the fact that the purpose of grounded theory is to creating a theory rather than testing one, the design of this study was not suitable to test the findings and the conceptual framework does not provide a practical design consideration. However, throughout the research many questions has been raised, and along with the provided information, this thesis provides a foundation on which the future studies can build upon and venture in to new theories.

## REFERENCES

- Acun, V. & Yilmazer, S. Investigating the effect of indoor soundscaping towards employee's speech privacy. Paper presented at EuroNoise 2015, European Acoustical Association (June, 2015), 2461-2466.
- Acousticator. (2012). Speech Transmission Index. Retrieved August 13, 2015, from [https://en.wikipedia.org/wiki/Speech\\_transmission\\_index#/media/File:STI\\_CIS\\_Scale.png](https://en.wikipedia.org/wiki/Speech_transmission_index#/media/File:STI_CIS_Scale.png)
- Argyrous, G. (2011). *Statistics for research: with a guide to SPSS*. Sage Publications.
- Barrett, L. F., & Bliss-Moreau, E. (2009). Affect as a Psychological Primitive. In M. Zanna (Ed.), *Advances in experimental social psychology* (Vol. 41, pp. 167-218). Burlington: Elsevier.
- Basco, L. (2011). Soundwalking. A new tool for urban regeneration
- Bradley, J. S. (2003). The acoustical design of conventional open plan offices. *Canadian Acoustics*, 31(2), 23-34.
- Brambilla, G., Gallo, V., Asdrubali, F., & D'Alessandro, F. (2013). The perceived quality of soundscape in three urban parks in Rome. *The Journal of the Acoustical Society of America*, 134(1), 832-839.
- Brambilla, G., Maffei, L., Di Gabriele, M., & Gallo, V. (2013). Merging physical parameters and laboratory subjective ratings for the soundscape assessment of urban squares. *The Journal of the Acoustical Society of America*, 134(1), 782-790.

- Brown, A. L., Kang, J., & Gjestland, T. (2011). Towards standardization in soundscape preference assessment. *Applied Acoustics*, 72(6), 387-392.
- Corbin, J., & Strauss, A. (1998). *Basics of qualitative research: Techniques and procedures for developing grounded theory*. Sage publications.
- Davies, W. J., Adams, M. D., Bruce, N. S., Cain, R., Carlyle, A., Cusack, P., Hall, D. A., Hume, K. I., Irwin, A., Jennings, P., Marselle, M., Plack, C. J. and Poxon, J. (2013) Perception of soundscapes: An interdisciplinary approach, *Applied Acoustics*, 74(2), 224-231.
- Dey, I. (1999). *Grounding grounded theory: Guidelines for qualitative inquiry*. Academic Press.
- Dökmeci, P., & Jian, K. A. N. G. (2012, April). A comparative case study of indoor soundscape approach on objective analyses and subjective evaluations of libraries. In *Acoustics 2012*.
- Egan, M. David. *Architectural acoustics*. McGraw-Hill Custom Publishing, 1988.
- Ekkekakis, P. (2013). *The measurement of affect, mood, and emotion: A guide for health-behavioral research*. Cambridge University Press.
- Fiebig, A., & Schulte-Fortkamp, B. (2004). The importance of the Grounded Theory with respect to soundscape evaluation. In *Proceedings of CFA/DAGA(Vol. 4)*.
- Guski, R., Felscher-Suhr, U., & Schuemer, R. (1999). The concept of noise annoyance: how international experts see it. *Journal of sound and vibration*, 223(4), 513-527.
- Haapakangas, A., Kankkunen, E., Hongisto, V., Virjonen, P., Oliva, D., & Keskinen, E. (2011). Effects of five speech masking sounds on performance and acoustic satisfaction. Implications for open-plan offices. *Acta Acustica united with Acustica*, 97(4), 641-655.
- Hoda, R., Noble, J., & Marshall, S. (2011, October). Grounded theory for geeks. In *Proceedings of the 18th Conference on Pattern Languages of Programs* (p. 24). ACM.

- Hongisto, V., Keränen, J., & Larm, P. (2004). Simple model for the acoustical design of open-plan offices. *Acta acustica united with Acustica*, 90(3), 481-495.
- Hongisto, V. (2005). A model predicting the effect of speech of varying intelligibility on work performance. *Indoor air*, 15(6), 458-468.
- Isen, A. M., Daubman, K. A., & Nowicki, G. P. (1987). Positive affect facilitates creative problem solving. *Journal of personality and social psychology*, 52(6), 1122.
- ISO. (2012). ISO 3382-3 Measurement of Room Acoustic Parameters – Part 3: Open Plan Offices. Genève, Switzerland: ISO.
- ISO. (2014). ISO 12913-1: Part 1: Definition and conceptual framework. Genève, Switzerland: ISO.
- Jahncke, H., Hongisto, V. and Virjonen, P. (2013) Cognitive performance during irrelevant speech: Effects of speech intelligibility and office-task characteristics, *Applied Acoustics*, 74(3), 307-316.
- Jones, M., & Alony, I. (2011). Guiding the use of Grounded Theory in Doctoral studies – an example from the Australian film industry [Electronic version]. *International Journal of Doctoral Studies*, 6, 96-114.
- Kim, J. and de Dear, R. (2013) Workspace satisfaction: The privacy-communication trade-off in open-plan offices, *Journal of Environmental Psychology*, 36(18-26).
- Koelega, H. S. (1987). Environmental annoyance: characterization, measurement, and control: proceedings of the International Symposium on Environmental Annoyance, held at the Conference Centre Woudschoten, the Netherlands, 15-18 September 1986. Elsevier Science Publishers.
- Krause, B. L. 1993. "The Niche Hypothesis: A hidden symphony of animal sounds, the origins of musical expression and the health of habitats," *The Explorers Journal*, Winter 1993, pp. 156-160.

- Kitapçı, K. (2008) Effects of speech intelligibility on computer based task performance in open plan offices, Unpublished M.F.A Thesis. (Advisor: Semiha Yilmazer). Bilkent University, Ankara, Turkey.
- Kwallek, N., Woodson, H., Lewis, C. M., & Sales, C. (1997). Impact of three interior color schemes on worker mood and performance relative to individual environmental sensitivity. *Color Research and Application*, 22(2), 121-132.
- Mackrill, J., Cain, R. and Jennings, P. (2013) Experiencing the hospital ward soundscape: Towards a model, *Journal of Environmental Psychology*, 36(1-8).
- Martin, E. A., & Kerns, J. G. (2011). The influence of positive mood on different aspects of cognitive control. *Cognition and Emotion*, 25(2), 265-279.
- Okcu, S., Ryherd, E. E., Zimring, C., & Samuels, O. (2011). Soundscape evaluations in two critical healthcare settings with different designs. *The Journal of the Acoustical Society of America*, 130(3), 1348-1358.
- OSHA Standard. (2004). Occupational Safety and Health Administration Law and Regulations. Retrieved from: <https://www.osha.gov/law-regs.html>
- Ozcevik, A. & Yuksel, C. Z. (2012). A field study on the subjective evaluation of soundscape. Proceedings of the Acoustics 2012 Nantes Conference. Nantes, 23-27 April.
- Reducing a rooms reverberation time will soften or eliminate an echo. (n.d.). Retrieved August 12, 2015, from <http://www.melfoamacoustics.com/reverberation-times.html>
- Rossing, T. D. (1990). *The Science of Sound* (2nd ed.). Addison-Wesley Publishing.
- Russell, J., & Barrett, L. F. (1999). Core affect, prototypical emotional episodes, and other things called emotion: Dissecting the elephant. *Journal of Personality and Social Psychology*, 805-819.
- Schafer, R. M. (1977). *The Soundscape: our sonic environment and the Turning of the world*. Rochester, Vermont: Destiny Books.

- Schacter, D. L. (2011). *Psychology Second Edition*, 41 Madison Avenue, New York, NY 10010.
- Schnall, S. (2010). Affect, Mood and Emotions. *International Encyclopaedia of Education*, 544-548
- Strauss, A., & Corbin, J. (1990). *Basics of qualitative research: Grounded theory procedures and techniques*. London. Sage Publications.
- Truax, B. (2001). *Acoustic communication (Vol. 1)*. Greenwood Publishing Group.
- Westerkamp, H., Woog, A., Kallmann, H., & Truax, B. (2006, July 2). World Soundscape Project (A. McIntosh, Ed.). Retrieved June 27, 2015, from <http://www.thecanadianencyclopedia.com/en/article/world-soundscape-project/>
- Wrightson, K. (1999). An Introduction to Acousti Ecology *Journal of Electroacoustic Music*, 12, March 1999. [http://www.sonicartsnetwork.org/main\\_index.html](http://www.sonicartsnetwork.org/main_index.html)
- Virjonen, P., Keränen, J., & Hongisto, V. (2009). Determination of acoustical conditions in open-plan offices: proposal for new measurement method and target values. *Acta Acustica united with Acustica*, 95(2), 279-290.
- Yang, M., & Kang, J. (2013). Psychoacoustical evaluation of natural and urban sounds in soundscapes. *The Journal of the Acoustical Society of America*, 134(1), 840-851.

## **APPENDIX A**

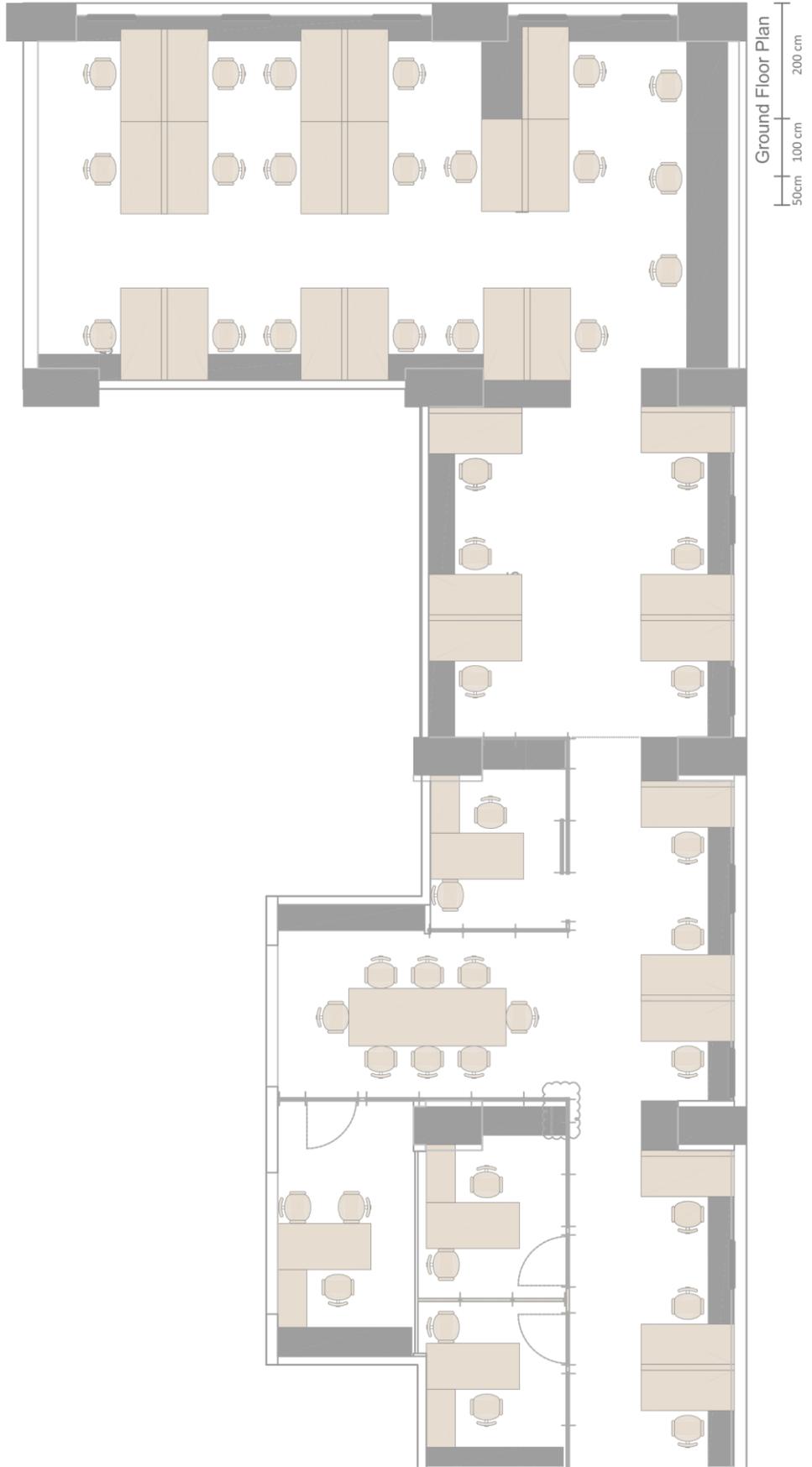


Figure A 1: Öncüoğlu + ACP Architects (Office ARCH) Ground floor plan.

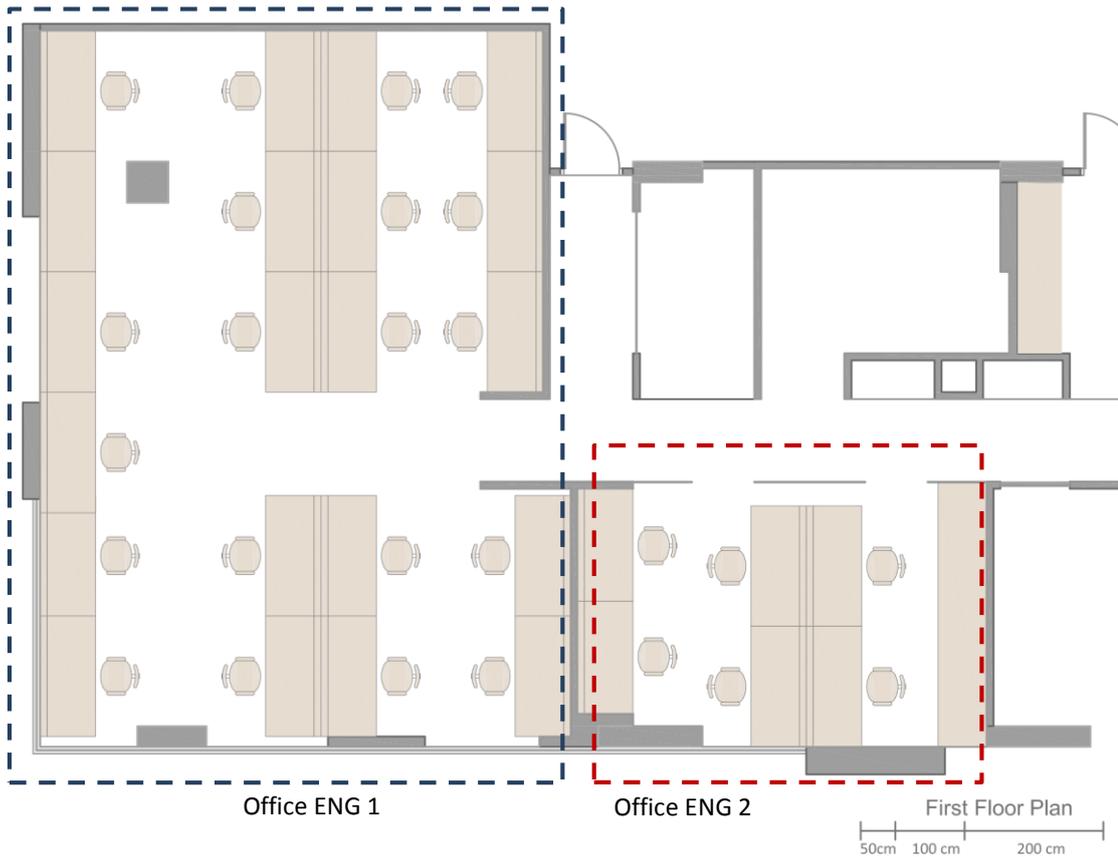
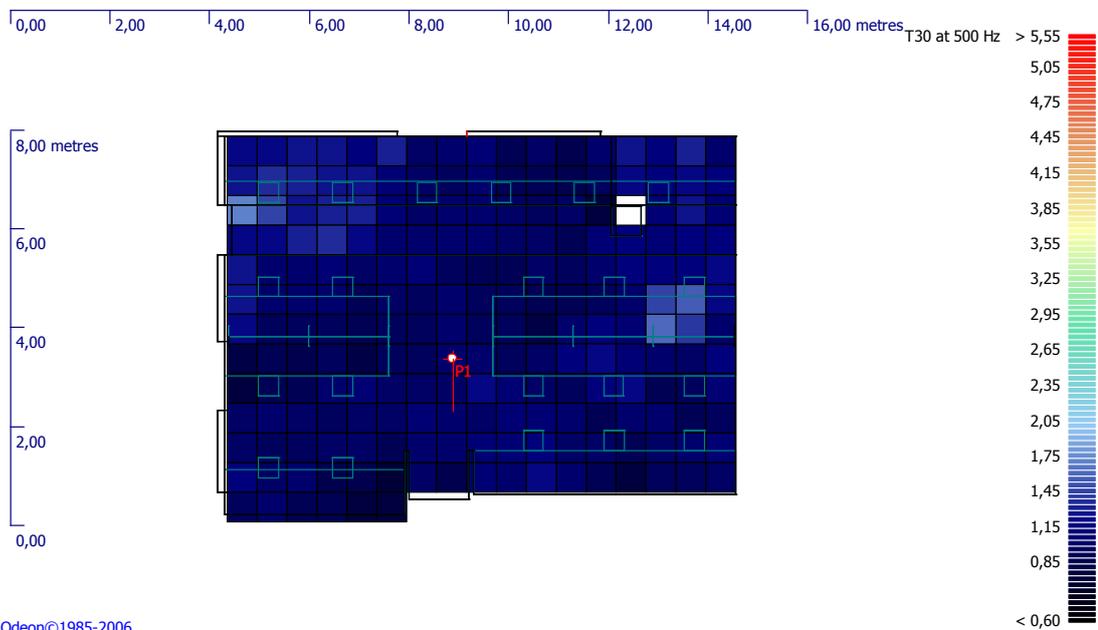


Figure A 2: Promer Engineering Consultancy (Office ENG) first floor plan. Blue dash line shows the main office space (Office ENG 1) and red dash line shows the subspace of the main office space (Office ENG 2).



Odeon©1985-2006

Figure A 3: Office ENG 1 grid response of Reverberation time  $T_{30}$  at 500 Hz.

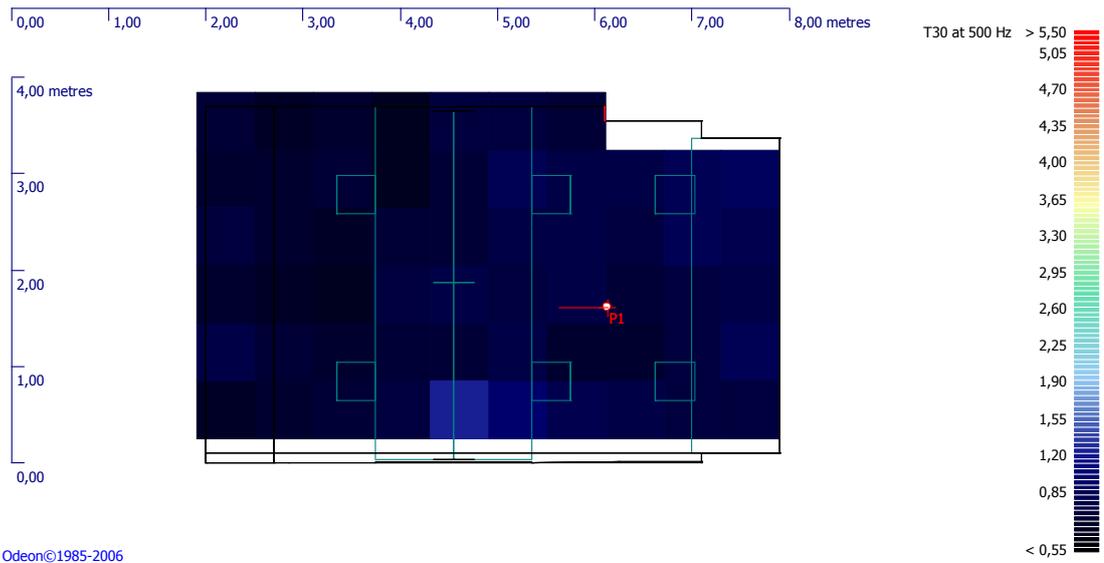


Figure A 4: Office ENG 2 grid response of Reverberation time T30 at 500 Hz.

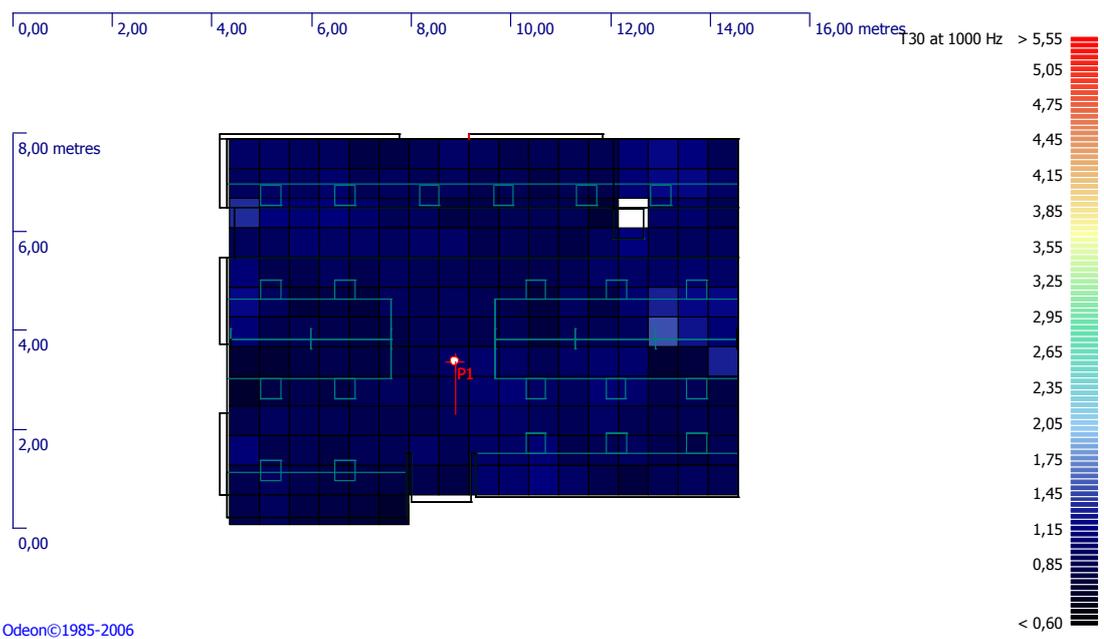


Figure A 5: Office ENG 1 grid response of Reverberation time T30 at 1000 Hz

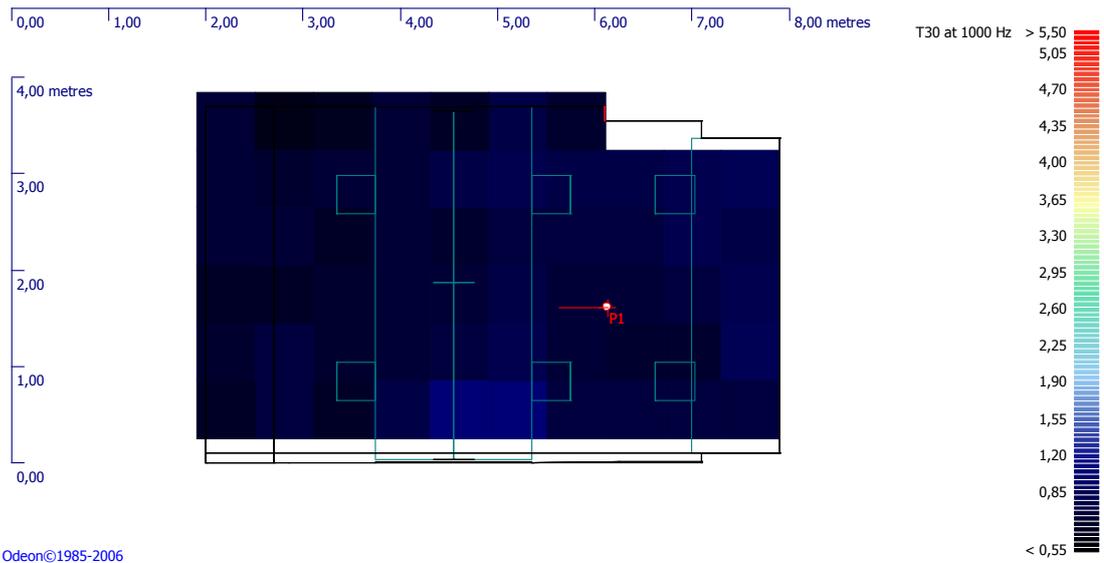


Figure A 6: Office ENG 2 grid response of Reverberation time T30 at 1000 Hz

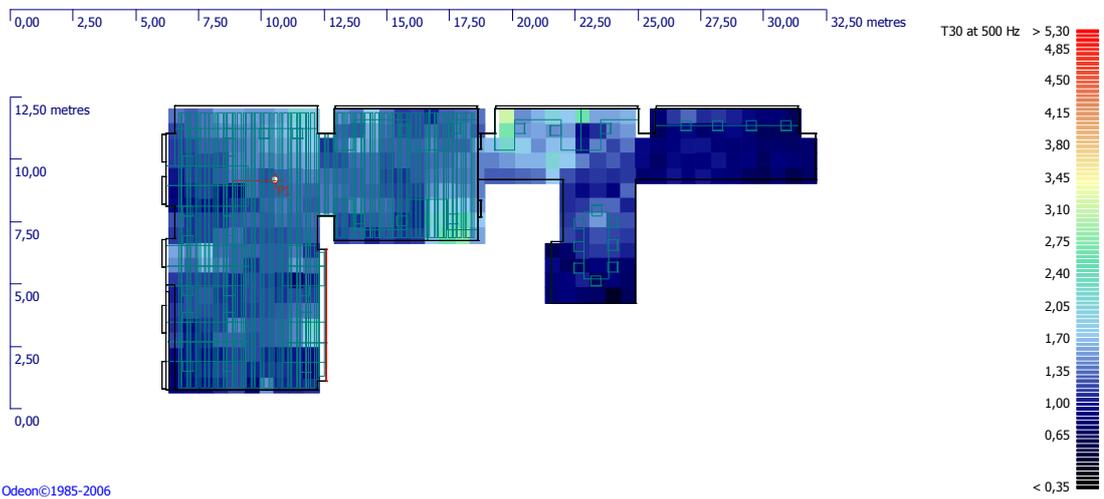


Figure A 7: Office ARCH grid response of Reverberation time T30 at 500 Hz

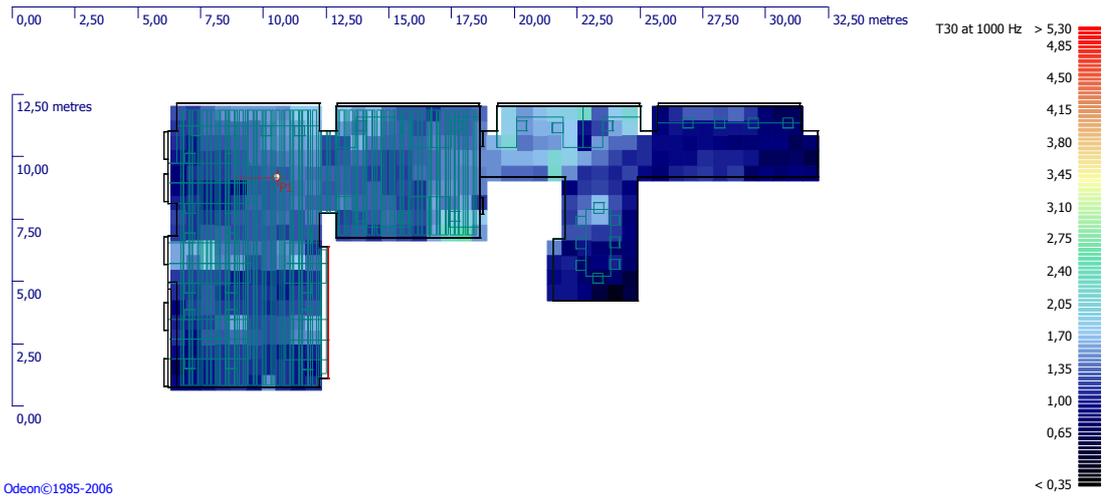


Figure A 8: Office ARCH grid response of Reverberation time T30 at 1000 Hz

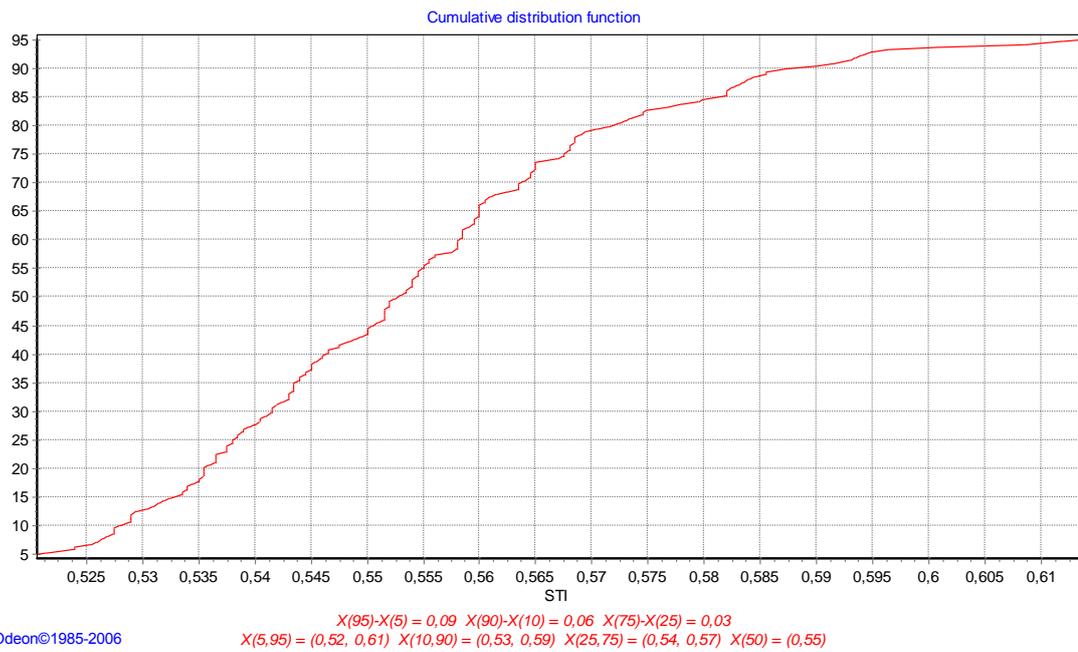


Figure A 9: Office ENG 1 STI cumulative distribution graph.

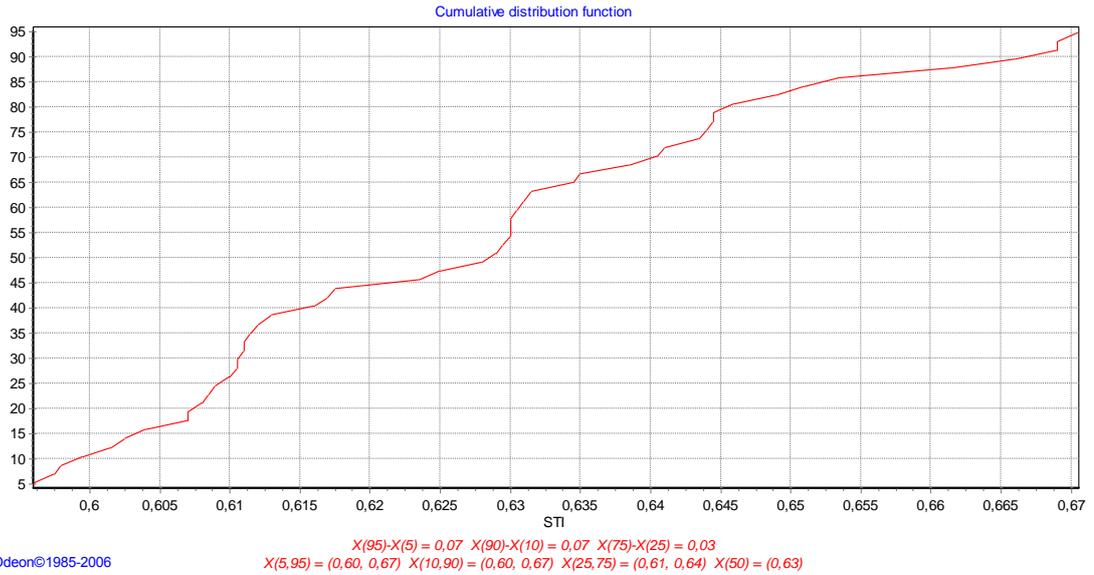


Figure A 10: Office ENG 2 STI cumulative distribution graph.

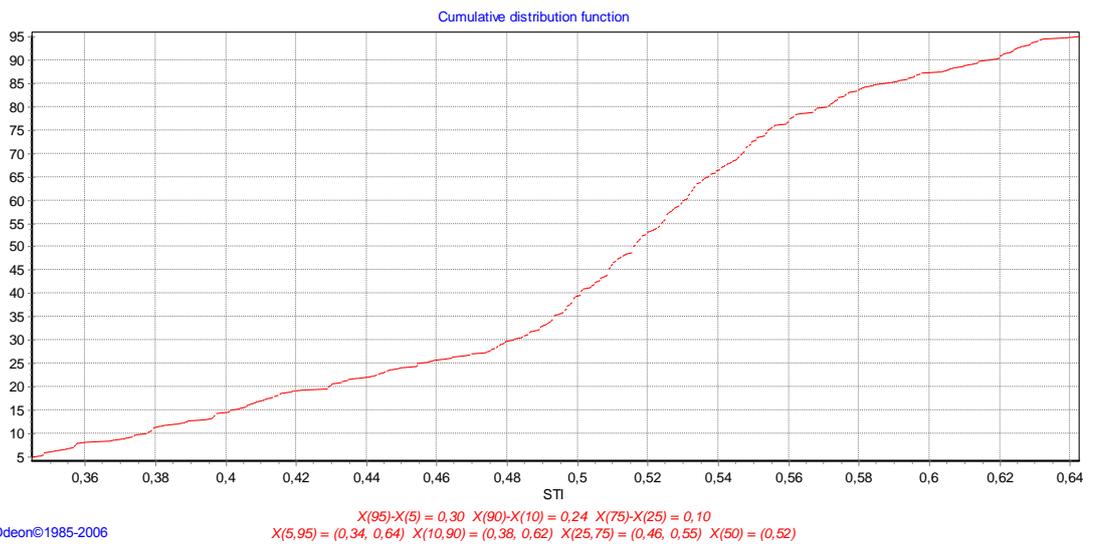


Figure A 11: Office ARCH STI cumulative distribution graph.

## **APPENDIX B**

Table B 1: Coding Framework which shows all themes, their descriptions and frequency of mentions.

<b>Theme</b>	<b>Explanation</b>	<b>Freq.</b>
<b>Sound Sources &amp; Sound Levels</b>	Sound sources and sound levels that contributes to soundscape	435
<b>Behavioural Attitudes</b>	Comments describing how individuals cope with negative perception	150
<b>Perception of Sound</b>	Individuals subjective perception of sound and its effects	146
<b>Physical Properties of Space</b>	Physical Properties of space that effect individuals perceptions	56
<b>Environmental Factors</b>	Factors within the work environment that effect employees' perception of soundscape	43
<b>Temporal Factors</b>	Individuals comments regarding how time and activity effects perception of sound	38
<b>Effects on Task Performance</b>	Comments regarding the effect of sound sources towards job performance	36
<b>Sound Preference</b>	Individuals sound preference depending on personal preference, task and mood	35
<b>Work Type</b>	Comments regarding employees' duties	35
<b>Employee Characteristics</b>	Comments regarding individuals employees' health, general mood and attitudes towards different situations	28

Table B 2: Themes and categories generated from the coding procedure

<b>Themes</b>	<b>Categories</b>	<b>Themes</b>	<b>Categories</b>
<b>Sound Sources &amp; Sound Levels</b>	Human Mechanical & Electronical Outside Music  High Sound Levels Low Sound Levels	<b>Effects on Task Performance</b>	Positive Negative Neutral
<b>Environmental Factors</b>	Crowded Tense Relax Workload Privacy Context of Sound	<b>Sound Preference</b>	Task Dependant Mood Dependant Personal Preference
<b>Physical Attributes of Space</b>	Heating Lighting Office Layout Proximity Problems	<b>Work Type</b>	Routine Work Works that Require Focus
<b>Temporal Factors</b>	Sound Duration Activity	<b>Behavioural Attitudes</b>	Adaptation Isolation Intervention
<b>Perception of Sound</b>	<p><b>Positive</b> Promoting Motivation Promoting Concentration Promoting Privacy Promoting Relaxation Workplace Satisfaction</p> <p><b>Neutral</b> Indifference</p> <p><b>Negative</b> Loss of Concentration Decreasing Motivation Annoyance Disturbance Irritability Fatigue Nervousness Restriction</p>	<b>Employee Characteristics</b>	Behavioural Tendency Mood Health Experience

Table B 3: Sound Sources perceived by the employees' of both offices

OFFICE ARCH Sound Sources				OFFICE ENG Sound Sources			
Source	Freq.	Source	Freq.	Source	Freq.	Source	Freq.
<b>Human Generated Sounds:</b>	<b>87</b>	<b>Mechanical &amp; Electronical Sounds</b>	<b>53</b>	<b>Human Generated Sounds:</b>	<b>106</b>	<b>Mechanical &amp; Electronical Sounds</b>	<b>58</b>
Speech	25	Keyboard & Mouse	13	Speech	50	Keyboard & Mouse	12
Group Conversation	4	Printer/Plotter	16	Group Conversation	10	Printer/Plotter	13
Phone Conversation	18	Computer Fan	10	Phone Conversation	5	Computer Fan	6
Rattling Noise	1	Air Condition	4	Rattling Noise	6	Telephone	16
Footsteps	6	Telephone	7	Footsteps	11	General	8
Laughing	1	General	3	General	18		
<b>Sound Source Music:</b>	<b>30</b>	<b>Outside Sounds:</b>	<b>16</b>	<b>Sound Source Music:</b>	<b>44</b>	<b>Outside Sounds:</b>	<b>18</b>
		Nature	5			Nature	3
		Animal	11			Animal	8
		Traffic	2			Traffic	2
						General	5

Table B 4: Air Absorption coefficients for Reverberation Time formula

Air absorption m per m <sup>2</sup>			
Air at	2000 Hz	4000 Hz	8000 Hz
20°C, 30% RH	0.012	0.038	0.136
20°C, 50% RH	0.010	0.024	0.086

## PANAS Questionnaire

This scale consists of a number of words that describe different feelings and emotions. Read each item and then list the number from the scale below next to each word. **Indicate to what extent you feel this way right now, that is, at the present moment OR indicate the extent you have felt this way over the past week.**

1	2	3	4	5
Very slightly or Not at All (Çok Hafif veya Hiç)	A Little (Biraz)	Moderately (Orta)	Quite a Bit (Epeyce)	Extremely (Aşırı Miktarda)

_____ 1. Interested (İlgili)	_____ 11. Irritable (Tedirgin)
_____ 2. Distressed (Sıkıntılı)	_____ 12. Alert (Alarmed)
_____ 3. Excited (Heyecanlı)	_____ 13. Ashamed (Utanmış)
_____ 4. Upset (Mutsuz)	_____ 14. Inspired (İlhamlı)
_____ 5. Strong (Güçlü)	_____ 15. Nervous (Sinirli)
_____ 6. Guilty (Suçlu)	_____ 16. Determined (Kararlı)
_____ 7. Scared (Ürkmüş)	_____ 17. Attentive (Dikkatli)
_____ 8. Hostile (Düşmanca)	_____ 18. Jittery (Asabi)
_____ 9. Enthusiastic (Hevesli)	_____ 19. Active (Aktif)
_____ 10. Proud (Gururlu)	_____ 20. Afraid (Korkmuş)

Figure B 1: PANAS questionnaire

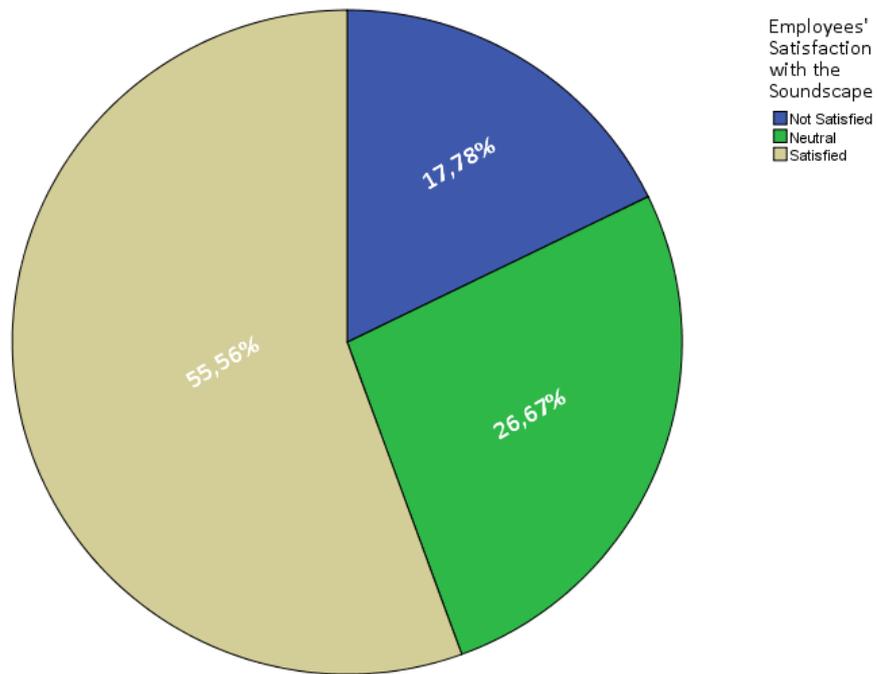


Figure B 1: Employees satisfaction with the soundscape.

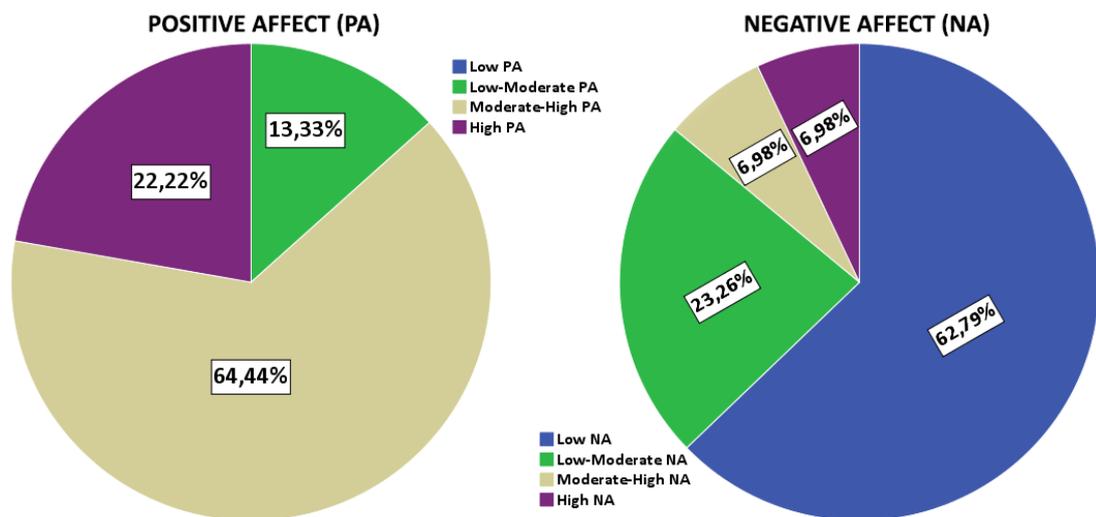


Figure B 2: Positive Affect (PA) and Negative Affect (PA) results.

1. What do you expect to hear in your work environment?
2. What are the positive and negative sound sources within your work environment?
3. Why do you think these sound sources are positive or negative?
4. What do you prefer to hear?
5. Do you associate any sound with your current work environment?
6. How does these sound sources effect your task performance?
7. Are you satisfied with the soundscape of your work environment?

Figure B 3: The 7 core questions, that are prepared before the starting the semi-structured interviews.