To my dear grandparents,

Nurten & Ali Çeken

Fatma & Mustafa Dökmeci

ACOUSTICAL COMFORT EVALUATION IN ENCLOSED PUBLIC SPACES WITH A CENTRAL ATRIUM: A CASE STUDY IN FOOD COURT OF CEPA SHOPPING CENTER, ANKARA

A THESIS
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MASTER OF FINE ARTS

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September, 2009

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ABSTRACT

ACOUSTICAL COMFORT EVALUATION IN ENCLOSED PUBLIC SPACES WITH A CENTRAL ATRIUM: A CASE STUDY IN FOOD COURT OF CEPA SHOPPING CENTER, ANKARA

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Physical comfort requirements of users as thermal, visual, and acoustic comfort should be considered and studied in detail when designing and planning public spaces. The subjective auditory perception needs to be evaluated parallel with the objective acoustical incidences in a space. The food court area of CEPA Shopping Center with an atrium and a glass dome ceiling, in the capital city of Turkey, Ankara is chosen for the case. The aim of this study is to investigate acoustical parameters of the space via computer simulation program and examine the effect of architectural features of the space namely; central atrium, glass dome and the existing material applications. Considering the relationship between the users' noise annoyance and the equivalent continuous sound pressure level (Leq) is also intended in this study. The research techniques are computer simulations, noise measurements and questionnaires. Acoustical parameters; reverberation time (RT), early decay time (EDT), sound transmission index (STI) and equivalent continuous sound pressure level (Leq) values are obtained by simulations and measurements. Questionnaires are used for understanding the noise annoyance and auditory perception of the users. The results show that the noise annoyance ratings correlate well with the Leq variances. The most dominantly perceived and the most annoying sound found to be correlated with the highest percentage for speech noise in the food court. Decay time (T30, EDT) results of the space that are derived from the ODEON 6.5 software are found to be very long as expected with a central atrium, glass dome ceiling and highly reflected material applications. In addition, the food court area is defined to be poor in terms of STI. High Leq values as well as long decay times that are present in the space are noted as factors increasing the noise annoyance of the users.

KEY WORDS: acoustic comfort, acoustical parameters, noise annoyance, central atrium, public spaces, food court

ÖZET

MERKEZİ GALERİ BOŞLUĞU BULUNAN TOPLU KULLANIM MEKANLARINDA AKUSTİK KONFOR DEĞERLENDİRMESİ: CEPA ALIŞVERİŞ MERKEZİ YEMEK ALANI ÖRNEĞİNDE

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Toplu kullanım mekanlarının planlama ve tasarım sürecinde, kullanıcıların fiziksel konfor gereksinimleri göz önünde bulundurulmalı ve detaylı çalışılmalıdır. İşitsel algının değerlendirilmesi, mekanda oluşan akustik olgular ile paralel olarak ele alınmalıdır. Bu çalışma için, Ankara'da yer alan, cam kubbe tavanlı ve bu tavanın altında tasarlanmış bir galeri boşluğuna sahip CEPA Alışveriş Merkezi seçilmiştir. Bu çalışmanın amacı, mekanın akustik özelliklerini bilgisayarda benzetim yoluyla incelemek ve merkezi galeri boşluğu (atriyum), cam kubbe ve mevcut malzeme uygulamaları gibi mimari ögelerin mekana etkisini araştırmaktır. Çalışmada ayrıca, eşdeğer sürekli gürültü düzeyleri (Leq) ile kullanıcıların gürültü rahatsızlıkları arasındaki ilişkinin irdelenmesi de amaçlanmıştır. Araştırma teknikleri olarak, bilgisayarda benzetim çalışmaları, gürültü ölçümleri, ve anketler kullanılmıştır. Çınlama süresi (RT), erken sönümlenme üresi (EDT), eşdeğer sürekli gürültü düzeyleri (Leq) ve konuşma iletim indisi (STI) benzetim çalışmaları veya ölçümler ile elde edilmiiştir. Anketler, kullanıcıların gürültü rahatsızlığı seviyelerini ve işitsel algılarını ortaya koymak için uygulanmıştır. Sonuçlar, gün içerisinde değişkenlik gösteren Leq değerleri ile kullanıcıların gürültü rahatsızlıklarının birbirleri ile doğrudan ilişki gösterdiğini vurgulamaktadır. Anket çalışmalarından elde edilen sonuçlar, en baskın olarak algılanan ses ve en rahatsız edici sesin doğrudan ilişkili olduğunu ve insan sesi olarak nitelendirildiğini göstermektedir. ODEON 6.5 akustik analiz programından elde edilen sönümlenme süreleri (T30, EDT) ile mekanın uzun çınlama sürelerine ve düşük anlaşılabilirlik değerlerine sahip olduğu görülmüş ve neden olarak, merkezi galeri boşluğu, cam kubbe tavan ve ses yansıtıcı malzemeler verilmiştir. Ek olarak, konuşma iletim indisi (STI) açısından, yemek alanı yetersiz bulunmuştur. Yüksek eşdeğer sürekli gürültü düzeyleri ve uzun çınlama süreleri, CEPA yemek katında bulunan kullanıcıların gürültü rahatsızlıklarının artmasına yol açan faktörler olarak saptanmıştır.

ANAHTAR KELİMELER: akustik konfor, akustik parametreler, gürültü rahatsızlığı, merkezi galeri boşluğu (atriyum), toplu kullanım alanları, yemek alanı

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TABLE OF CONTENTS

SIGNATURE PAGE ii
ABSTRACT iii
ÖZET iv
ACKNOWLEDGMENTS v
TABLE OF CONTENTS vi
LIST OF TABLES ix
LIST OF FIGURES x

1. INTRODUCTION **1**

1.1. General 1
1.2. Aim and Scope 4
1.3. Structure of the Thesis 5

2. ACOUSTICAL REQUIREMENTS IN ENCLOSED PUBLIC SPACES **8**

2.1 Objective Criteria 8
2.1.1. Reverberation Time (RT) 8
2.1.2. Early Decay Time (EDT) 11
2.1.3. Speech Transmission Index (STI) 12
2.1.4. Sound Pressure Level (SPL) and Equivalent Continuous Sound Pressure Level (Leq) 13
2.2. Subjective Criteria 14
2.2.1. Pitch 14
2.2.2. Loudness and Loudness Level 16
2.2.3. Noisiness and Annoyance 18
2.3. Architectural Characteristics and Requirements of the Enclosed ‘non acoustic’ Spaces 19
2.3.1. Acoustical Requirements of Enclosed ‘non-acoustic space’ 20
2.3.2. Diffuse Field Requirements 21
2.3.3. Effects of Volume, Shape and Size 21

2.3.4. Acoustical Characteristics of Atrium Void 22
2.3.5. Acoustical Characteristics of Domes 24
2.3.6. Materials and Applications 25

3. DESIGN OF THE STUDY **29**
3.1. Research Questions 29
3.2. Objectives 30
3.3. Hypotheses 30
3.4. Methodology 31
3.4.1. Computer Simulations 31
3.4.2. Noise Measurements 34
3.4.3. Questionnaires 34
3.5. Case: Food Court of CEPA Shopping Center 35
3.5.1. Architecture, Shape and Size 35
3.5.2. Materials and Applications 38

4. OBJECTIVE AND SUBJECTIVE EVALUATION ON FOOD COURT OF CEPA SHOPPING CENTER **40**
4.1. Computer Simulation Results 40
4.1.1. Reverberation Time (RT) 43
4.1.2. Early Decay Time (EDT) 48
4.1.3. Speech Transmission Index (STI) 51
4.1.4. Sound Pressure Level (SPL) and A-weighted Sound Pressure Level (SPL-A) 52
4.2. Noise Measurements 53
4.2.1. Results of Equivalent Continuous Sound Pressure Level (Leq) Measurements 54
4.2.2. Sound Pressure Level (SPL-A) Variances for Different Frequencies 58

4.3. Questionnaire Results 60
4.3.1. Demographics and Space Utilization Characteristics 60
4.3.2. Noise Annoyance Ratings and Auditory
Perception 62
4.3.3. Response to Different Sound Sources 63
4.3.4. Noise Annoyance Rating Variations on Weekdays-
Weekends 64
4.3.5. Time Spent Preferences and Noise Annoyance Ratings
in the Food Court 65

5. DISCUSSION **67**
5.1. Analyzing the Acoustical Characteristics of the Food Court in CEPA 67
5.2. Relationships between Leq Measurements and Noise Annoyance
Ratings of the Food Court Users 72

6. CONCLUSION **77**

REFERENCES **79**

APPENDICES **84**
Appendix A1: AutoCAD Drawings 85
Appendix B1: Distributions Maps of Computer Simulation 88
Appendix C1: Questionnaires and Correlations 95
Appendix C2: Auditory Perception and Noise Annoyance Survey 102

LIST OF TABLES

Table 2.1. Quality scores in relation with STI (or RASTI) values 13

Table 2.2. Change in subjective loudness due to the change in sound level 17

Table 4.1. Material list and sound absorption coefficients used for the model...43

Table 4.2. Simulated EDT and RT values for 63-8000 frequency range 51

Table 4.3. Simulated SPL values for 63-8000 frequency range 53

Table 4.4. Measured Leq values at different times during weekdays (WD) and weekends (WE) 56

Table 4.5. Differing SPL-A values measured on specified locations on weekends 60

Table 4.6. Differing SPL-A values measured on specified locations on weekdays 61

Table 4.7. Age distribution of the sample group 62

Table 4.8. User's noise annoyance ratings for weekdays and weekends 66

Table 5.1. Leq values compared with different volumes of three varied atriums.69

LIST OF FIGURES

Figure 2.1. Fletcher and Munson curves of loudness level contours 18
Figure 3.1. Axonometric view of CEPA Shopping Center showing source and receiver positions from the computer simulation....................33
Figure 3.2. 3D view of the model from the receiver.................................34
Figure 3.3. Bruel & Kjaer Type 2230 Sound Level Meter 35
Figure 3.4. The site plan of CEPA Shopping Center and Bauhaus Store 37
Figure 3.5. Partial plan of CEPA Shopping Center, 3rd Floor......................37
Figure 3.6. The cross-section of CEPA Shopping Center 38
Figure 3.7. The longitudinal section of CEPA Shopping Center..................38
Figure 3.8. Glass dome ceiling located at the center of the atrium void and the details of the dome structure...39
Figure 3.9. The overall food court area with the atrium void and glass dome ceiling.. 40
Figure 4.1. Plan of CEPA Shopping Center showing source and receiver positions from the computer simulation..................................41
Figure 4.2. Longitudinal section of CEPA Shopping Center showing source and receiver positions from the computer simulation..............42
Figure 4.3. Cross-section of CEPA Shopping Center showing source and receiver positions from the computer simulation...................42
Figure 4.4. 3D view of the model as seen from the source.......................43
Figure 4.5. Bar chart showing the total absorption area of current materials assigned for the computer simulation 44
Figure 4.6. Estimated global reverberation times of Sabine, Eyring and Arau-Punchades derived by material properties..............................45
Figure 4.7. Bar chart showing the estimated global reverberation times of T30 and T20.. 46

Figure 4.8. Free path distribution map 46
Figure 4.9. Cumulative distribution function graph of T30 at 1000 Hz 47
Figure 4.10. T30 distribution map for 1000 Hz 48
Figure 4.11. Cumulative distribution function graph of EDT at 1000 Hz 49
Figure 4.12. EDT distribution map for 1000 Hz 50
Figure 4.13. Graph showing RT and EDT results of simulation for 63-8000 frequency range 51
Figure 4.14. STI distribution map 52
Figure 4.15. SPL distribution map for 1000 Hz 53
Figure 4.16. SPL (A) distribution map 54
Figure 4.17. Food court plan showing the Leq measurement points 55
Figure 4.18. Mean Leq values for weekends and weekdays of different hours 57
Figure 4.19. Measured Leq values for weekends (WE) and weekdays (WD) of different hours and locations 58
Figure 4.20. Averaged SPL-A level changes for different frequencies between 63-8000 HZ 59
Figure 4.21. Distribution on the education level 62
Figure 4.22. Noise annoyance ratings in CEPA and in food court 64
Figure 4.23. Distribution of users according to the time spent in food court 67
Figure 5.1. Rating percentages for annoyance from other people in food court related with mean Leq values of weekdays and weekends 76

Figure 5.2. Linear regression graph for annoyance of food court users from the overall noise in CEPA and the measured Leq values 77
Figure 5.3. Rating percentages for annoyance from other people in food court related with different day types and times of the day ..78

1. INTRODUCTION

1.1. General

Designing public spaces is an important field that should be considered and studied in detail. There are some basic requirements regarding the physical comfort of the users that should be included in planning a public space. These requirements can be exemplified as, thermal, visual, and acoustic comfort in an enclosed, semi-enclosed or open space.

The field of acoustical design and the understanding of auditory perception have begun to be considered by architects and designers with the innovations in the acoustical materials and by the development of certain computer modeling and analyzer software. The will for creating better living environments could be fulfilled by such computer software. These environments (mainly enclosed spaces as the focus of this study) are used by the individuals of the society who are generally unaware of the environment (open or enclosed) that they spent time while they use it on regular basis. A great deal of work should be accomplished by the architects and acoustical designers in renovating the existent buildings and providing acoustical consultancy for those planning to be constructed in the near future.

There are many studies focusing on enclosed 'acoustic' spaces that deal with either music or opera. Such spaces are exemplified as concert halls or opera houses. The acoustical formations and parametric researches are carried out on designing better performance spaces for the performers as well as better acoustical environments for the spectators. In these certain spaces, subjective attributes such as, intimacy, liveness, warmth, loudness of direct sound and reverberant sound, balance and blend, diffusion and ensemble are very crucial (Long, 2006). These attributes play important role for the subjective acoustical evaluation of a space and should be considered and well designed.

Auditoriums, meeting rooms and lecture halls are also studied in detail in the literature. In such spaces, adequate loudness, uniform sound distribution, appropriate reverberation, high signal-to-noise ratios and low levels of background noise are crucial objective criteria for designing such spaces (Long, 2006). The subjective assessment is based primarily on the speech intelligibility as well as clarity and definition and can be tested by objective parameters such as articulation index or speech transmission index and real-size measurements (Long, 2006).

Studies in the literature are concentrated mainly on acoustic spaces such as auditoriums or concert halls yet, other 'non-acoustics' enclosed public spaces such as shopping centers or other leisure venues (restaurant, cafes and bars) need more attention (Kang, 2003, Chen, and Kang, 2004). Low sound pressure levels, appropriate reverberation and low ambient noise levels are crucial for better subjective evaluation of these spaces. Loudness, annoyance, privacy and clarity are the subjective criteria that should be studied in these enclosed public spaces. Speech interference and intelligibility is one important topic that is studied in detail at the food court area of shopping malls or dining spaces that gained speed in recent years (Kang, 2002, Navarro, Pimentel, 2007). Especially, studies on the objective and subjective relations in such spaces should be carried on to present better evaluation on noise annoyance or intelligibility, yet such studies are lacking in the literature (Kang, 2004).

The architectural elements in an enclosure have significant effects on distinctive acoustical formation. In this point, the architects and designers should not forget that architecture is not only visual yet there are many other criteria for a space to be well appreciated and comfortable. The examples for such architectural elements are atriums and domes used commonly in many public spaces. Both of these architectural elements lead to malign acoustical formations, so should be carefully used by appropriate preventions. Articles regarding atriums and their acoustical characteristics gained speed in recent years (Bradley, 1998). Comparative studies of Bradley, Chen and Mahdavi are the examples that concentrate on atriums of different types in buildings having varied functions.

Studies on enclosed spaces with domes (Inoe, Sugino, Katou, and Imaizumi, 2009) or concave surfaces have been carried out especially regarding religious places such as domes in mosques or barrel-vaulted ceilings in churches and curved rear walls in auditoriums (Sü, and Yılmazer, 2006). These elements used as an important architectural feature in an enclosure results in focus of reflected sound and echo (Egan, 1988). So, there is a need to carefully examine how such architectural elements would affect the overall space regarding physical comfort requirements.

Developing measurement tools that are designed for the real-size acoustical measurements and room acoustics analyzer software such as ODEON or CATT-Acoustics provide a great deal of opportunities for the architects and acoustical designers during the design or renovation period of a building (Rindel, 2000). Different acoustical parameters and room responses of an enclosure are determined either by measurements or simulations prior to the construction or renovation stage. In addition, subjective evaluation and auditory perception classifications of users should not be left out when a renovation assignment is carried out. Architectural solutions as acoustical material applications and interior interventions that are based solely on the objective parametric results of a space do not provide all the necessary acoustical information regarding that space. Yet, the user's auditory perception and comfort ratings are clues that lead to crucial renovation strategies in creating better acoustical environments that are working parallel with its designated function.

The previous studies mainly concentrated on the objective characteristics and acoustical formations in open, semi-open or enclosed spaces. Data related to the auditory perception and noise annoyance in such spaces is lacking in the literature (Kang, 2004). On the other hand, studies that focus on the relations and correlations between objective acoustical parameters and noise annoyance are rather less yet gained speed during recent years (Yang, and Kang, 2005, Zannin, Calixto, Diniz, and Ferreira, 2003). In addition, many studies can be seen in the literature regarding the objective acoustical parameters of open/urban public spaces (Yang, and Kang, 2005, Payne, and Devine-Wright, 2007) as the new terminology 'soundscape approach and design' came into use with its main focus on larger scales mostly being urban parks and open city environments.

1.2. Aim and Scope

As the basic consideration, this study is designed to understand the relationship of the acoustical conditions and the auditory perception of the users with respect to the architectural and spatial properties of the food court area in CEPA Shopping Center. The aim of this study is to analyze the acoustical characteristics of the space with a central atrium and a glass dome ceiling. In addition, measured equivalent continuous sound pressure level (Leq) and the users' noise annoyance ratings are considered to put forth the relationship between them.

One other concern is to define the acoustical properties of the space and then investigate upon the effects of such acoustical formations on the auditory perception and noise annoyance of the users. The demographical differences (gender, age, and education), users' space utilization and auditory perception variances are discussed with respect to the users' noise annoyance ratings.

1.3. Structure of the Thesis

The thesis is structured under six main parts including the introduction part that is consisted of a general introduction with information regarding previous studies on objective and subjective assessment, aim and scope and structure of the thesis.

'Acoustical Requirements in Enclosed Public Spaces', is the second chapter that includes the basic criteria and definitions used in the thesis. This part is divided into three sections as, the objective criteria, the subjective criteria and the architectural characteristics and requirements of the enclosed 'non-acoustic' spaces, characteristics and requirements. In the objective criteria section, definitions of the objective parameters used in the field of acoustics are given. These acoustical parameters are, reverberation time (RT), early decay time (EDT), speech transmission index (STI), sound pressure level (SPL), and equivalent continuous sound pressure level (leq)that are relevant to the main topic of the thesis and discussed all through the study. In the subjective criteria section, definitions of the subjective parameters, pitch, loudness and loudness level, and noisiness and annoyance are given. In the third section, architectural characteristics and requirements of the enclosed 'non-acoustic' spaces, Acoustical Requirements of Enclosed 'non-acoustic space', diffuse field requirements, effects of volume, shape and size, acoustical characteristics of atrium void, acoustical characteristics of domes, materials and applications have been stated.

The third chapter is titled as, 'Design of the Study', that consists of hypothesis, research questions, objectives, methodology and the case: food court of CEPA Shopping Center. In the methodology part, the objective and subjective assessment tools that are used in this study are explained in detail. In the case part, architectural features and material characteristics of CEPA Shopping Center is described. The third chapter mainly provides prior knowledge about the methods used for the study and case site providing a link between chapters two; acoustical requirements in enclosed public spaces and chapter four; objective and subjective evaluation on food court of CEPA shopping center.

In the fourth chapter entitled 'objective and subjective evaluation on food court of CEPA shopping center' the results of the computer simulations, noise measurement, questionnaires and their relation with each other are discussed. This chapter is composed of four sections. Under computer simulations; reverberation time (RT), early decay time (EDT), speech transmission index (STI), and sound pressure level (SPL and SPL-A) results are given and discussed. The real-size measurements section consists of the results regarding equivalent continuous sound pressure level (Leq). The questionnaire results are discussed under the following headings; demographics and users' space utilization characteristics, noise annoyance ratings and auditory perception, response to different sound sources, and noise annoyance rating variations on weekdays and weekends and time spent preferences and noise annoyance ratings in the food court.

'Discussion' is the fifth chapter, which is followed by the 'Conclusion' that is made on the sixth chapter of the thesis. Discussion chapter is divided into three sections and involves discussions on the results of all three different methods and the relations among them are explained. The statistical analysis, correlations and comparisons on objective and subjective outcomes are included in this section. The conclusion part points out the most significant and relevant results derived from the outcomes. The references and appendices follow the conclusion part.

2. ACOUSTICAL REQUIREMENTS IN ENCLOSED PUBLIC SPACES

There are important acoustical requirements that should be considered for enclosed spaces. These requirements and preferred acoustical characteristics of a space vary accordingly with the usage function. The acoustical requirements can be examined under three sections as; the objective criteria, the subjective criteria and the architectural characteristics. The combination of all these three criteria and their detailed analysis put forth the acoustical characteristics of the space.

2.1. Objective Criteria

The objective acoustical criteria of an enclosed space present the acoustical parameters and formations within that space. These criteria are measurable and tangible information obtained by varied assessment tools. The shopping centers are enclosed non-acoustic public spaces, where acoustical parameters as, reverberation time, early decay time, sound pressure level, and speech transmission index are more important and determinative upon the characteristics of the space. Especially, Leq is used for the noise measurements for such public enclosed spaces (Long, 2006).

2.1.1. Reverberation Time (RT)

'Reverberation' is the remaining sound that can be heard for sometime after the termination of the source (Maekawa, and Lord, 1994). In auditory perception, propagation and decay of each sound is very important (Lawrence, 1989). In order to describe reverberation in a numerical format the terminology, 'reverberation time' is used. Reverberation time is the fundamental concept for evaluating the sound field in an enclosed space and it is defined as at a given frequency or frequency band "the time taken for a sound to decay by 60 decibels (dB) after the source is stopped" (Lawrence, 1989, p. 91).

There are three main formulas trying to put forth the calculation of reverberation time (RT), namely are, Sabine's, Eyring's and Millington-Sette's formulas. In Sabine's formula, information on the size of the room (mainly the volume) and the total room absorption in sabins is required to calculate the time required to decay 60 decibels (dB) after the source is stopped (Egan, 1988). It is generally used by testing laboratories and for calculating RT in architectural spaces having diffuse sound field conditions and spaces that do not vary widely in dimensions (Egan, 1988).

1) Sabine's Formula:

$$T_{60} = 0{,}161\ V / A$$

where,

T_{60} = reverberation time, or the time it takes for sound to decrease by 60 dB in a room (s)

V = volume of the room (m^3)

A = total area of absorption in the room (sabins)

Eyring's and Millington-Sette's formulas are more applicable to rooms with very high absorption ratios as recording studios or anechoic chambers.

2) Millington-Sette's Formula:

$$T_{60} = 0{,}161\ V / -S_T \ln \left[1 - \Sigma\ (S_i\ \alpha_i / S_T)\right]$$

where,

T_{60} = reverberation time, or the time it takes for sound to decrease by 60 dB in a room (sec)

V = volume of the room (m^3)

S_T = total surface area (m^2)

While Sabine considered the sound to decay continuously until it disappears, Eyring introduces the new concept of disappearance of the reflected sounds. The idea in his formula is when the sound source is stopped; all the other reflected sounds disappear simultaneously, creating a situation of a perfect absorption ($\alpha \ll 1$). This is the reason of its applicability of Eyring's formula in high absorbent rooms (Maekawa, and Lord, 1994). Eyring-Knudsen formula includes the air absorption where "the energy attenuation constant due to air absorption m is related to temperature and humidity (Maekawa and Lord, 1994, p. 80). The three mentioned formulas are as follows (Long, 2006);

3) Eyring's Formula:

$T_{60} = 0,161\ V / -S_T \ln (1 - \bar{\alpha})$

where,

T_{60} = reverberation time, or the time it takes for sound to decrease by 60 dB in a room (sec)

V = volume of the room (m^3)

S_T = total surface area (m^2)

$\bar{\alpha}$ = the average sabine absorption coefficient and

$$\overline{\alpha} = \frac{A}{S}$$

A = total absorption in square metres (m^2)

S = total surface area (m^2)

In order to correctly use the above formulas, the room or spaces should not widely vary according to their size, shape and especially in absorption/reflection ratios. In highly reflective rooms with no absorptive material treatments, a reverberant sound field occurs by the repeatedly reflected sound waves from the boundaries (Harris, 1994). Similarly, "when floor and ceiling are highly absorptive but walls reflective, the reflected sounds in the vertical direction decay rapidly while the reflected sounds in the horizontal direction remain repeating reflections with slow decay, thus the decay curve bends"(Maekawa, Lord, 1994, p. 81). This kind of a room is not considered as a diffuse field and the reverberation time for 60 dB decay cannot be calculated by any formulas.

2.1.2. Early Decay Time (EDT)

Early decay time (EDT) is "the initial sound decay in the first 10 to 20 milliseconds (ms) of drop after the initial burst" that can be caused by an impulse source such as gunshot, bursting balloon or electronically induced pulse (Long, 2006, p. 312). EDT is also defined as the reverberation time, measured over the first 10 dB of the decay. EDT gives a more subjective evaluation of the reverberation time as it well relates with speech transmission index (STI). EDT can be computed for every octave band or frequency range and same as other RT values expressed in milliseconds (ms).

Cocktail party effect and signal-to-noise ratio are other two very important subjects that are directly linked with decay time and intelligibility (Kang, 2002). In public enclosures, where speech noise is generated by the occupants of the space, intelligibility becomes one important aspect. Kang (2002) explains a significant feature of dining spaces as; "for a given listener, the sound from the talker(s) in his/her conversation group (e.g. a dining table) is regarded as signal, and the sound from the other talkers is regarded as ambient noise. It has been stated that "speech can be understood at a direct field level of 50.3 dB and assuming the background noise due to other sources is low, the two people can converse comfortably at separation distance of 3.9 meters" (Long, 2006, p. 604). Yet, when the noise level increases in the space, eventually people tend to get closer or rise their voices for better intelligibility, resulting noise levels getting increased by additional occupants (Long, 2006). In such an environments decay times as well as sound pressure levels are crucial and should be controlled by specific acoustical interventions. Sound absorption mechanisms and materials are key elements for such treatments. When the absorption coefficient is higher in the enclosure the signal-to-noise ratio gets lower leading to better intelligibility (Long, 2006).

2.1.3. Speech Transmission Index (STI)

Speech transmission index is a machine measure of intelligibility of speech and directly depends on the background noise level, the reverberation time, and the size of the room. The analysis of speech is simulated during 20th century by scientists to better understand the characteristic (Lawrence, 1989). It is known that "the intelligibility inside any enclosure depends on signal to noise ratio (SNR), the signal level and reverberant field" and be best described by three different criteria, speech transmission index (STI), rapid speech transmission index (RASTI) and percentage loss of consonants (%AlCons) (Hammad, 2000, pg. 185). RASTI (room acoustics speech transmission index or rapid speech transmission index) can be described as the simplified version of STI for specified use. Similar with articulation index (AI) and %AlCons, STI is the direct measure of speech intelligibility (SI) and are all numerical schemes (Long, 2006).

Table 2.1. Quality scores in relation with STI (or RASTI) values (Long, 2006, p. 152).

Quality Score	STI (or RASTI) Value
Bad	0-0.32
Poor	0.32-0.45
Fair	0.45-0.60
Good	0.60-0.75
Excellent	0.75-1.0

The range of STI is between 0 = completely unintelligible – 1 = perfect intelligibility, so a value of 0.5 is required for most enclosed spaces and also expressed in Table 2.1.

2.1.4. Sound Pressure Level (SPL) and Equivalent Continuous Sound Pressure Level (Leq)

Before discussing sound pressure level (SPL), concepts of sound pressure and sound energy should be well understood. As “pressure is a force per unit area”, the progress of sound energy occurs rapidly, producing very small changes n the atmosphere that makes it possible for human ear to hear the sound incidences (Egan, 1988, p. 2). SPL is the most commonly used indicator for the acoustic wave strength and is nearly the same concept with sound intensity. SPL well correlates with the human perception of loudness and gives important clues regarding the noise annoyance ratings (Long, 2006). According to the explanations given by Maekawa and Lord (1994), “sound intensity is proportional to the square of the sound pressure and the particle velocity" (pg. 7) and in order to measure sound intensity or sound pressure the logarithmic scale with unit decibel (dB) is used.

Equivalent continuous sound pressure level (Leq) is used as an index for noise. It is given in terms of dBA, the A-weighted sound that fluctuates over a period of time. In addition, it has been noted in the literature that Leq correlates well with human reaction (Long, 2006). That is the main reason that Leq is chosen for the main deterministic objective acoustical parameter for the noise measurements.

2.2. Subjective Criteria

The subjective criteria within an enclosed public space consists the abstract and perceptual characteristics of sound. Such measures can be achieved by detecting and analyzing the human response to some basic components of sound. Human hearing and auditory perception play crucial role for the concept of subjective criteria in an enclosed space. Subjective assessment tools are the key elements used to assess information on this concept.

2.2.1. Pitch

Egan states the definition of pitch as "the subjective response of human hearing to frequency" (1988, p. 4) and notes that low frequencies are classified as boomy and high frequencies as screechy. Similar to electronic filters, the cochlear filters in the ear act as parallel band-pass filters that separate the incoming sounds into their spectral components and the perception of different frequencies occur as the result of such filtering (Long, 2006).

For acoustical measurements, analysis and specifications, the frequency range is divided into sections called bands. The most common standard division is "10 octave bands identified by their center frequencies: 31.5 – 63 – 125 – 250 – 500 – 1000 – 2000 – 4000 – 8000 – 16000 hertz (Hz)" (Egan, 1998, p. 4). A healthy young person has the hearing range of 20 - 20,000 Hz (hearing range of an old person gets lowered as 20-2000 or 4000 Hz) and the speaking range of 125 – 8000 Hz (Egan, 1988). Another important concept is the speech octave band that is critical for human hearing, which are; 500-1000-2000-4000 Hz respectively (Long, 2006). So, the sound pressure level peaks are rather crucial at these certain frequency ranges for intelligibility of speech.

Although, pitch is defined as the perceived frequency, it is rather complicated as the intensity and waveform may also be effective in the perception. In addition, a sound with a constant pitch is called tone and in order for human ear the sense the pitch, the duration should not be too short (Maekawa, and Lord, 1994) and too weak. This phenomenon can be explained by the example, "if a 100 Hz tone is sounded at 60 dB and then at 80dB, the louder sound will be perceived as having a lower pitch" especially for frequencies below 300 Hz, however for mid frequencies ranging from 500 Hz to 3000 Hz, pitch gets independent from the intensity and begins to increase with the level for the frequencies above 4000 Hz (Long, 2006, p. 81). The psychoacoustic experiments try to experiment on the perception of pitch for that sense. In addition, it should be noted that, "the pitch of a complex sound is perceived as that of the frequency which is the highest common factor of the frequencies of all the component sounds" (Maekawa, and Lord, 1994, p. 22).

2.2.2. Loudness and Loudness Level

Lord (2006) defined loudness as the "human perception of the magnitude of a sound" and although this definition would mean that the determination of loudness is possible by the measured intensity of a sound, such a relation does not exist (p. 81). Physiologically, loudness depends on the nerve impulses that reach to brain in a certain time coming from the different parts of the cochlea resulting variations with the frequency content of the sound (Long, 2006). It should also be noted that even the same sound is heard at different intensities, the evaluation of a listener or listeners would vary as the sensitivity sound is highly affected by "frequency content, time of occurrence, duration of sound and psychological factors as emotion and expectations" (Egan, 1988, p. 21).

The apparent loudness for the subjective judgment, the changes in the sound level are given in Table 2.2. As it can be noted, a normal hearing person can barely notice the sound level change for 3 decibels. It is also said that an educated ear has the ability to detect a 2 decibels change, yet 1 decibel change is imperceptible for human ear (Egan, 1988).

Table 2.2. Change in subjective loudness due to the change in sound level (Egan, 1988, p. 21).

Change in Sound Level (dB)	Change in Apparent Loudness
1	Imperceptible (except for tones)
3	Just barely perceptible
6	Clearly noticeable

10	About twice (or half) as loud
20	About 4 times (or one-forth) as loud

In addition, as subjective sensation is not proportional with objective intensity of loudness, a standardized measurement term is found, entitled loudness level measured in 'phons' (Maekawa, and Lord, 1994). During 1920's and 1930's a series of measurements had been done at Bell Laboratories and in 1933 Fletcher and Munson published a study stating the relation of the loudness of a tone by frequency and subjective evaluation of the listeners (Long, 2006). The results had lead to the formation of the Fletcher-Munson curves (see Figure 2.1.) presenting a group of loudness level contours. In the presented graph, loudness level is equalized with the sound pressure level (intensity) at 1000 Hz, which was also the fixed reference tone in the experiments (Long, 2006). Some crucial outcomes can be noted as, maximum sensitivity is between 3000 and 5000 Hz and decreases at higher levels (Maekawa and Lord, 1994).

One other outcome of the Fletcher's experiment is the established relationship between loudness level measured in *phons* and subjective loudness expressed in 'sones'. In other words, the unit of relative loudness of 1 sone is equal to the loudness level of 40 phons at 1000 Hz and when the sound is heard twice as loud as 1 sone, the relative loudness becomes equal to 2 sones (Maekawa, and Lord, 1994). As a result, the loudness (in sones) versus loudness level (in phons) presents a linear graph (Long, 2006).

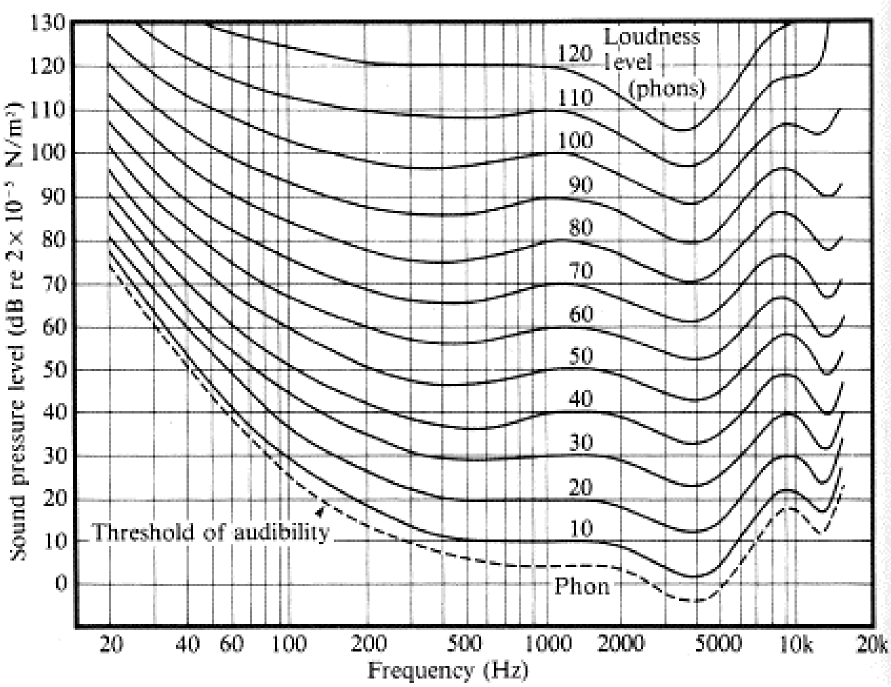


Figure 2.1. Fletcher and Munson curves of loudness level contours (Long, 2006, p.83).

2.2.3. Noisiness and Annoyance

Similar with the judgment of loudness in sones, a subjective rating scale is developed to measure noisiness in terms of 'noys'. In the study of Kryter (1970), it was asked to compare third-octave bands of noise at differing levels for the subjective judgment of relative or absolute noisiness and the results were differing from the loudness evaluation (Long, 2006). When the noisiness ratings in noys were converted into a decibel like scale, the terminology changed to perceived noise level (PNL) presented in the units of PNdB and the graph shows a linear formation with the noisiness doubling every 10 dB. It should be noted that PNL is mostly used in the evaluation o aircraft noise (Long, 2006).

Noisiness is affected by factors different than in loudness. These factors are mainly, the spectrum complexity (concentration of energy in pure tone or narrow frequency bands), total duration, the duration of the increase in level prior to the maximum level for non-impulsive sounds, and the increase in level in a 0.5 second interval for impulsive sounds (Long, 2006).

While the noisiness or loudness evaluation of individuals does not show great variance, annoyance is subjected to a highly personal judgment. Similarly, much of the studies are carried out in aircraft noise noting the response of people exposed to differing levels of noise (Long, 2006). There is not a defined measurement unit for annoyance; rather it gives information on the subjective evaluation of different types of sound and levels of noise in terms of descriptions and semantics.

The concept of human reaction to changes in sound pressure level has been determined by previous studies and experiments. The reactions to level changes can be described as; 1dB change to imperceptible (except for tones), 3 dB change to barely perceptible, 6 dB change to clearly noticeable, 10 dB change to doubling and 20 dB change to four times as loud (Egan, 1988).

2.3. Architectural Characteristics and Requirements of the Enclosed 'non-acoustic' Spaces

Architectural characteristics of a space are one important criterion that is effective on its acoustical properties. The acoustical formations within an enclosed space are directly related with the space properties and architectural elements that form the overall body of an enclosure. For this study, effects of volume, shape, and size of an enclosure as well as specific architectural elements such as atrium void and glass dome ceiling are discussed from the perspective of interior acoustical characteristics of an enclosure.

2.3.1. Acoustical Requirements of Enclosed 'non-acoustic space'

The acoustical requirements of varied spaces are assessed under two different topics regarding the function of the space as; 'acoustic space' and 'non-acoustic space' (Kang, 2003). Auditoriums, concert halls, theaters, opera houses, religious buildings (churches, cathedrals, mosques) and recording studios are examples of acoustic spaces as the main function in such spaces are related with music or perception of special acoustical indices that requires serious acoustical designs and treatments. On the other hand, the main function in residential, commercial, educational, health, public and industrial building is not related with acoustics, rather noise prevention and assessing acoustical comfort are the key requirements for these non-acoustic spaces.

As expected, the most studied spaces regarding acoustical requirements, treatments, varied parameters and auditory perception are the acoustic spaces. Studies on office buildings, lecture rooms and conference facilities gained speed in recent years by the need for better acoustical environments and with the developments of new implementations, techniques and materials regarding acoustics. On the other hand, public spaces such as retail outlets or shopping centers are some of the least studied spaces in the literature. The main reason is that they are commercial buildings and people have the opportunity to choose among many possibilities setting forth the best combination of thermal, visual and acoustic comfort. These comfort requirements of the users should be considered during the design process of the building and necessary material selections and applications should be introduced.

2.3.2. Diffuse Field Requirements

An enclosed space with a diffuse sound field is where many reflections and less amount of absorption occur. For an enclosed space to be considered as a diffuse field, sound energy should show a homogenous decay in the enclosure or room and a uniform sound propagation in all directions should be obtained (Maekawa, and Lord, 1994). Such homogenous and uniform distribution of sound energy could be possible by repeated reflections and diffractions of sound waves within the space. It is also defined by Long (2006) as "a diffuse field is one which there is an equal energy density at all points in the room" meaning that the time average of the mean-square sound pressure is the same and the flow of acoustic energy in all directions is equally probable (p. 298). For interior and enclosed spaces that are treated with marble, concrete or glass the reflection and diffraction of sound waves are more probable yet it might not be result in a diffuse sound field. The reflected part of the sound field in such spaces are called the reverberation field or reverberant field and mainly measured by decay times such as early decay times (EDT) or reverberation time (T30).

2.3.3. Effects of Volume, Shape and Size

Volume, shape and size of a room or a space have crucial importance for the acoustical formations within that space (Meissner, 2007). Therefore, how the acoustical characteristics vary accordingly with the changes in such architectural features should be assessed prior to the design and construction process for any kind of a building (Pavlovic -

Sumarac-, and Mijic, 2007). Especially for ‘acoustic’ spaces, the analysis of volume, shape and size have greater importance as there would be a need for special acoustical treatments for the interior volume.

Architectural features, surrounding walls, ceiling, and floor, are important for the analysis of the acoustical properties in a space. For example, the shape of a wall or ceiling to be concave or convex affects the sound reflection characteristics. In such cases, the concave surfaces tend to concentrate or focus the reflected sounds, and the convex surfaces lead to diffused reflection (Maekawa, and Lord, 1994).

Acoustics spaces such as concert halls, opera houses and auditoria are studied in great detail in the literature regarding plan forms, shape and volume. For example, Hetherington and Oldham (2007) analyze the geometric forms of auditoria and state that the majority are composed of basic plan forms and cross sections. They try to describe the efficiency of “different room forms for different acoustical functions with the aim of developing improved rules for the design of acoustical form and generate a large number of three dimensional models in which the geometries could be varied in a systematic manner” (p. 312).

2.3.4. Acoustical Characteristics of Atrium Void

The design of atriums with a covered court, arcade, galleria and winter garden came into use in the western world during the 19th century. Afterwards, the definition and the architectural formation of atriums changed in late 20th century with longer spans, better enclosures without glass ceiling that sits beneath towers (Hung, and Chow, 2001).

Atriums are architectural features that are widely used in mainly different kinds of buildings. Especially, public and office buildings are designed with varied forms of atriums to obtain better aesthetics as well as visual connection of the overall space.

In cold regions, buildings with atriums and glass skylights that sit over the atrium void provides pleasant, naturally lit and environmentally controlled spaces in all seasons of the year (Bradley, 1998). Based on their findings, Chen and Kang (2004) noted that, "the acoustic characteristics in atriums are rather different from those of other large and open spaces like auditoriums" (p. 107). In this case the centralized atrium creates "flow of space from level to level" and "visual emphasis from the horizontal galleria to the vertical atria" (Hung, and Chow, 2001, p. 287). Bradley (1998) agreed with his study on the acoustical measurements of ten differently functioned and architecturally varied atriums, that "the atria are found to be different to some other large indoor spaces" (p.2).

However, atrium void leads to crucial problems regarding acoustics because of its uncontrollable formation. One important property leading to bad acoustic indices is that atriums feature rather long reverberation at all frequencies. Chen and Kang (2004) pointed out the atrium void as one of the most important and commonly used architectural feature in shopping centers featuring the longest reverberation time at middle frequencies and the shortest at low frequencies. They indicated the reason of such reverberation characteristics as "the atrium roof glass and shop showcase glass absorb low frequency sounds while reflecting middle and high frequencies" (p. 109).

2.3.5. Acoustical Characteristics of Domes

Domes are commonly used in many enclosed spaces, omitting its distinct acoustical characteristic. Similarly with concave surfaces, domes are poor distributor of sound energy which leads to sound focus, dead spots and echo formation (Egan, 1988). In addition, reflected sound does not attenuate as it keeps reflecting within the dome itself increasing the reverberation time. When reflected sound does not decay in appropriate times the perceived sound becomes to be heard as hum of voices. Preventive actions include absorptive material treatments to diminish annoying sound reflections that reduces speech intelligibility (Egan, 1988).

In their article on the speech transmission performance and effect of acoustical remedies in a dome, Inoue et al (2009) evaluated the objective and subjective measures as well as their interrelations. They state that RASTI, EDT in 1 kHz, early-to-late arriving sound energy ratio and Ts (center time) corresponds well with speech intelligibility scores. One other important criterion they have been studied upon is the localization and direction of the sound source being at the center directed towards the dome at an angle of 90 degrees and the other being at the side but still towards the dome. The results of their study showed that reverberation time (T30) found to be longer at lower frequencies and shorter at higher frequencies. In addition, EDT and T30 values are not correlated with each other regarding different source locations. There are spots with longer EDT and shorter T30 values. They also noted that the sound field being excessively reverberant, the speech transmission performance varies for each source-receiver combination.

2.3.6. Materials and Applications

The design process of indoor spaces to obtain best possible acoustical conditions can be achieved by proper material selections and applications regarding the function of the building. Properties acoustical characteristics of the materials are the deterministic factors for their application techniques in a space.

One other important design criterion for better acoustical conditions for indoor spaces is to keep the background noise level as low as possible. The background noise occurrence for indoor spaces is mainly from HVAC or environmental sources. The necessary treatments to lower such unwanted background noise has to be done so that a more comfortable acoustical environment can be achieved.

The frequency range of the noise or any type of unwanted sound is very important for deciding on the most proper acoustical treatment. Fuchs (2001) reminded that 50 to 100 Hz is the range where noise control measurements becomes difficult and have high impact on speech intelligibility and acoustic comfort in auditoria and small enclosures. He emphasized the three important points regarding the usage of various noise control materials and their applications, as follows;

- avoiding mineral fiber usage on acoustic damping for hygiene and health issues,
- installing more resistive and non-abrasive materials for better durability under dirty and aggressive environments,
- replacing absorbing surfaces with large perforation or porous coverings of practically closed, even and smooth surfaces.

The key point is to combine the most suitable material regarding the function (absorber, reflector, and isolator) as an architectural component of the space. The innovative acoustical treatments are progressing with better and aesthetic appearances that can easily blend with the designated design of the space.

The term reflection is used to describe the incidence of a sound wave returning from a surface (Egan, 1988). The important criterion for obtaining reflection rather than absorption is to use a significantly larger reflector or reflective panel than the wavelength of the sound that it is designed to reflect. For any sound in which the frequency range and therefore, its wavelength distribution can be calculated, 2 or 4 times larger reflectors are sufficient. The main purpose of sound reflectors in an auditorium is to provide useful reinforcement of the direct sound to be reflected to audience who are not able to comprehend the direct sound. For music halls and opera houses, diffusers rather than direct sound reflectors are used. The main purpose of such diffusers is to scatter or random redistribute the sound wave to enhance the sensation of sound coming from all directions at equal levels (Egan, 1988). Yet, for spaces that are designed to be 'non-acoustic', excessive reflections are not needed. In such case, the reflected sound lowers the speech intelligibility and thereby causes noise annoyance.

In order to create better acoustical environments regarding enclosed 'non-acoustic' public spaces, absorbers should be introduced. There are three kinds of absorption mechanisms that are used in architectural design of indoor spaces; porous absorbers, panel absorbers and resonant absorbers (Lord, 2006). The absorption mechanisms have various applications under the main three types. For example, additions to porous absorbers are; spaced porous absorbers, thick porous materials with an air cavity backing and screened porous absorbers. Panel absorbers have the mechanism that is identified as nonporous absorption and sub types are, unbacked panel absorbers, air backed panel absorbers, perorated panel absorbers, perorated metal grills and air backed perforated panels. The third type is absorption by resonant absorbers with sub types, Helmholtz resonator absorbers, mass-air-mass resonators and quarter wave resonators (Long, 2006). Maekawa and Lord (1994) implied that, "in practice, these 3 types, or a combination of them are considered effective as absorptive building materials or as part of a construction" (pp.114-5).

All these three types of absorbers are effective at certain frequency ranges. Elliot (2002) stated that, active control of sound is most effective at low frequencies as the acoustic wavelength of sound waves is comparatively longer. The conventional passive noise control as absorption is more efficient for medium and high frequency sounds that have shorter wavelengths. As absorption is directly linked with the wavelength combinations of these different types gives a wider range of efficiency.

In order to understand how the material behaves for varying incident waves of different frequencies, reflection, transmission and absorption characteristics of the material has to be stated. Impedance tube testing or reverberation room method could be used to define the reflection, transmission and absorption coefficients of materials. As a result of these tests absorption coefficients of common materials have been determined and the values are put on a table with ranging frequencies (Long, 2006).

The porous absorbers are the most commonly used type that includes, fiberglass, mineral fiber products, fiberboard, pressed wood shavings, cotton, felt, open-cell neoprene foam, carpet, sintered metal and many other similar materials (Long, 2006). In his study, Berhault (2001) mentioned about various materials and their application techniques, in accordance with their characteristics. For a porous absorber namely, 'porous recycling glass', varied characteristics support different kinds of applications such as, self-bearing characteristics for applications on screens, mechanically robust for partitions, chemically resistant for enclosures, temperature resistive for linings, non-flammable for ceilings, water-proved for baffles, and finally easy recycling for silencer splitters.

Braccesi and Bracciali (1998) studied on the development and validation of the acoustical behaviors regarding porous materials that are classified as conventional or innovative. They noted that, "acoustic treatments with porous materials are widely used to reduce reverberation properties of closed spaces and to increase the transmission loss properties of multilayered panels" (p. 59). In order to estimate flow resistivity, they used reflection coefficient data and to estimate structure factor, least square fitting procedure.

There are many other mechanisms and materials with different acoustical properties, yet the examples in this chapter are chosen to be well related with the study case, CEPA Shopping Center. The criteria discussed in this chapter kept parallel with the case and the study objectives. The hypothesis and scope in relation with the method and assessment tools set forth the objective and subjective criteria and acoustical parameters that will be concentrated on the following chapters.

3. DESIGN OF THE STUDY

An experimental study is designed to put forth the objective parameters in the food court area in CEPA and the subjective noise annoyance ratings of the users in that food court area. The comparisons and correlations of these quantitative and qualitative assessments is tried to be accomplished for the evaluation of noise in enclosed public spaces. Other factors such as the demographics and the auditory perception classifications as well as the space utilization characteristics of the users are defined, analyzed and discussed in addition to the main correlated parameters. The methodology and assessment tools used for this study are chosen to fulfill either the quantitative (objective) or qualitative (subjective) approach.

3.1. Research Questions

The questions that should be investigated to form the basis of this study are;

1. What are the acoustical parameters, reverberation time (RT), early decay time (EDT), Speech Transmission Index (STI) of the food court area in CEPA shopping center?
2. What are the equivalent continuous sound pressure levels (Leq) in the food court area of CEPA in different time slot on the weekdays and the weekends?
3. What is the relationship between RT and STI?
4. How the users rate their noise annoyance in food court of CEPA and what are the users' auditory perception characteristics?
5. What kind of relations are there between equivalent continuous sound pressure levels (Leq) and noise annoyance ratings in food court area of CEPA?
6. What are the demographics of the users in food court and do these factors affect auditory perception and noise annoyance ratings?

3.2. Objectives

Each research question is fulfilled by the defined objectives;

1. To determine the acoustical parameters, reverberation time (RT), early decay time (EDT), Speech Transmission Index (STI) of the food court area in CEPA shopping center.

2. To assess the equivalent continuous sound pressure levels (Leq) in the food court area of CEPA in different time slot on the weekdays and the weekends.

3. To investigate the relationship between RT and STI.

4. To present the users' noise annoyance ratings and auditory perception characteristics in food court of CEPA.

5. To relate equivalent continuous sound pressure levels (Leq) and noise annoyance ratings in food court area of CEPA.

6. To put forth the demographical factors of the users in food court that may be affective on their auditory perception and noise annoyance ratings?

3.3. Hypotheses

The main hypothesis is, the presence of a central atrium with a glass dome ceiling leads to poor speech transmission index in CEPA Shopping Center.

The second hypothesis is that the measured mean Leq values well relate with the noise annoyance of CEPA Shopping Center food court users.

The third hypothesis is, auditory perception and noise annoyance could be interfered by the users' demographic, and activity patterns and could be effective on time spent preferences for this case.

3.4. Methodology

In order to fulfill the objectives of the study, three different methods are used as, computer simulations and noise measurements being the objective part and questionnaires as the subjective part. The three assessment tools used in the study are; Odeon 6.5 acoustical analyzer software, Dirac 3.0 room acoustics software and Bruel & Kjaer type 2230 sound level meter, and auditory perception and noise annoyance survey.

Cross-comparisons are done between the results of these three different methods and their relations with each other are evaluated by percentage frequencies, Mann-Whitney U test, Kruskal-Wallis One-way ANOVA test, Kendall's Tau-c test, linear regression analysis, and Pearson's chi-square test.

3.4.1. Computer Simulations

The first method is computer simulation that is done by Odeon 6.5 acoustical analyzer software deriving reverberation time (T30), early decay time (EDT), and speech transmission index (STI) results and distribution maps of defined acoustical parameters. There are many different technological achievements in the field of architectural acoustics regarding measurement and application techniques. Computer simulations are widely used for the acoustical calculations of the buildings and for assessing and modifying the acoustical characteristics of a space during the design phase (Rindel, 2000). The computer simulations for this study are done by ODEON 6.5 Room Acoustics Software. The software uses predictions algorithms as image-source method combined with ray tracing for the simulation of acoustical incidences and formations for interior spaces. The software is used to analyze and evaluate on acoustical properties of any kind of enclosed space as well as to assess recommendations for better acoustical environments (Rindel, 2000).

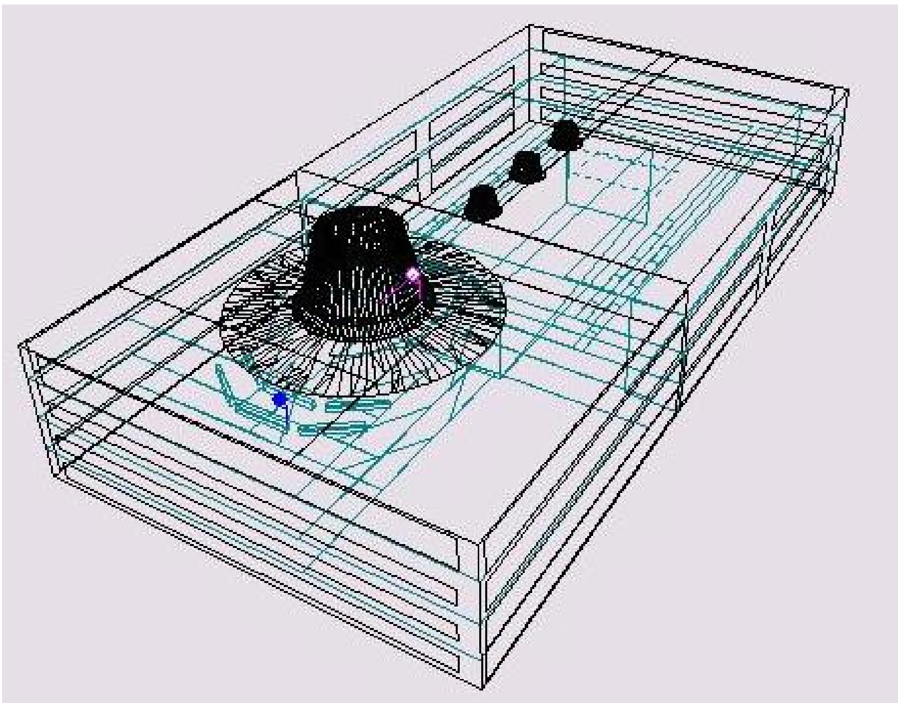


Figure 3.1. Axonometric view of CEPA Shopping Center showing source and receiver positions from the computer simulation.

In order to accomplish the computer simulations on ODEON 6.5 software, firstly, the 3D model of the building is drawn in AutoCAD 2007 with face modeling technique and saved in DXF format. The whole space is modeled for obtaining more reliable results. Then, it has been imported to ODEON 6.5 and the model is formed as seen in the Figure 3.1. After the model has been successfully imported (see Figure 3.2), the materials used in the space are determined and assigned to the identified surfaces. Then, the source and receiver positions are defined.

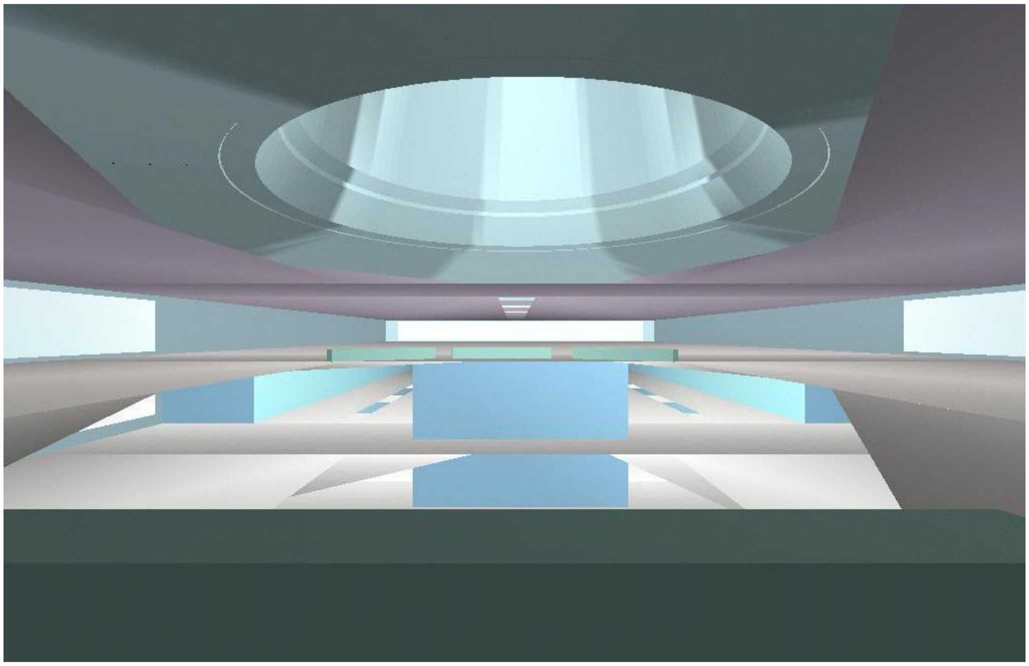


Figure 3.2. 3D view of the model from the receiver.

The enclosed space information given by ODEON Room Acoustics Software is as follows:

- Number of corners: 3246
- Number of surfaces: 1006
- Number of vertices: 4770
- Total surface area: 1155 m2
- Dimensions of the space:
  - X: 155 m
  - Y: 80 m
  - Z: 40 m

3.4.2. Noise Measurements

The second method is noise measurements on the soundscape. Dirac 3.0 room acoustics software and Bruel & Kjaer type 2230 sound level meter (see Figure 3.3) are used to measure equivalent continuous noise level (Leq). This measurement system detects various room acoustic parameters by using either external (impulse or noise) or internal (MLS signal, the sweep or swept sine, white noise and pink noise) excitation signals. In this study, the external excitation signals as impulse or noise are used. The mean Leq value is obtained for each frequency by one-minute measurements done on each measurement point and time.

Figure 3.3. Bruel & Kjaer Type 2230 Sound Level Meter.

3.4.3. Questionnaires

The third method is a questionnaire that is structured not only for evaluating the noise annoyance ratings of the users but also providing information on users' space utilization characteristics and demographics which may affect their auditory perception. In literature it is found that, a wide number of acoustical comfort evaluation surveys are developed in order to determine the most suitable noise annoyance rating scale. As noise is widely recognized as an important pollutant, many countries have developed their nation-wide noise abatement and control policies (Schultz, 1978). For this study, a survey including fourteen questions is prepared by in-depth examination and consideration of the previously recognized noise annoyance ratings (see Appendix C). The survey is most like a structured interview consisting of three main sections namely; 1- demographics, 2- users' space utilization, 3- auditory perception and noise annoyance ratings in food court area of CEPA. As Ader and Mellenbergh (2008) advise, all the questions are structured accordingly either with a Likert scale 1 to 5 (1- strongly disagree to 5-strongly agree), closed-ended questions (dichotomous, nominal-polytomous, or ordinal-polytomous) or open-ended questions.

3.5. The Case: Food Court Area of CEPA Shopping Center

3.5.1. Architecture, Shape and Size

CEPA Shopping Center is one of the widely used public spaces in Ankara. It is located at side of one of the main highways in the city across to Middle East Technical University. The localization of the shopping center is quite central by means of easy access. The shopping center is adjacent to one of the biggest house and garden equipment stores in the city called Bauhaus, which makes the whole center to be more preferred as the result of diverse shopping options (see Figure 3.4).

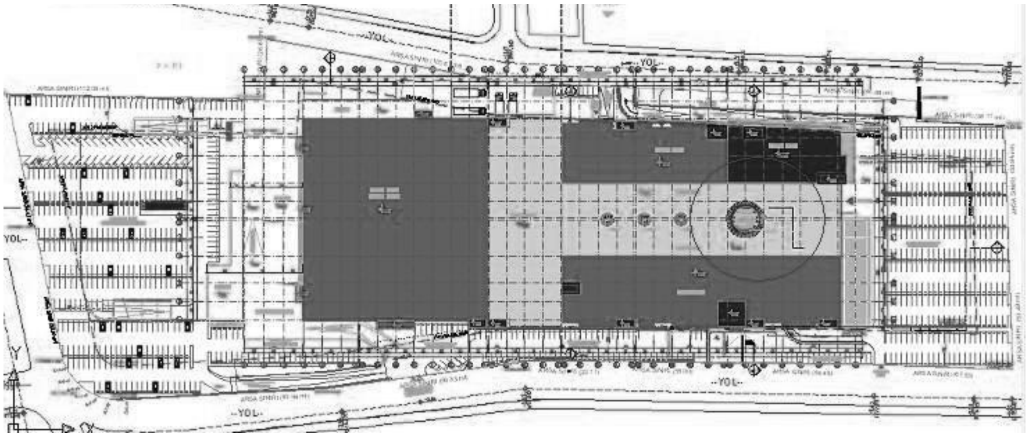


Figure 3.4. The site plan of CEPA Shopping Center and Bauhaus Store.

The height of the CEPA Shopping Center is 40 meters, the width is 80 meters, and the length is 155 meters. The total volume of the Center is 370,000 meter cubes. CEPA is designed with an atrium at the entrance level which connects all floors with each other. The spaces with different functions such as movie theatre, food court or shops are located separately from each other having a unified but at the same time distinct localizations. It should also been noted that, there is a fountain located at the entrance level of the shopping center, which acts as a sound source in the enclosed space.

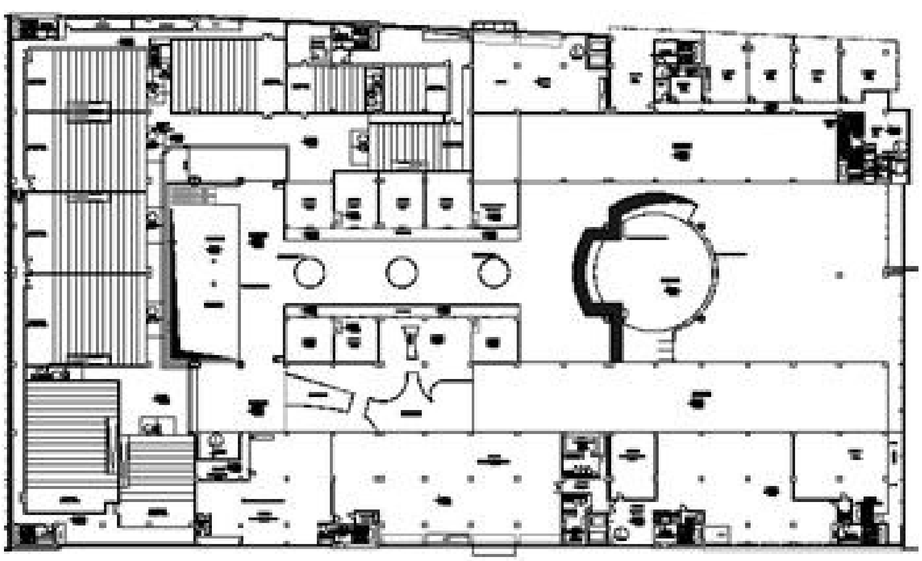


Figure 3.5. Partial plan of CEPA Shopping Center, 3rd Floor food court area.

The overall plan is rectangular and designed to have two different circulation axes which are linked to each other at the beginning and at the end (see Figure 3.5). The food court area, which is considered for this study is located at the third floor (see Figure 3.6).

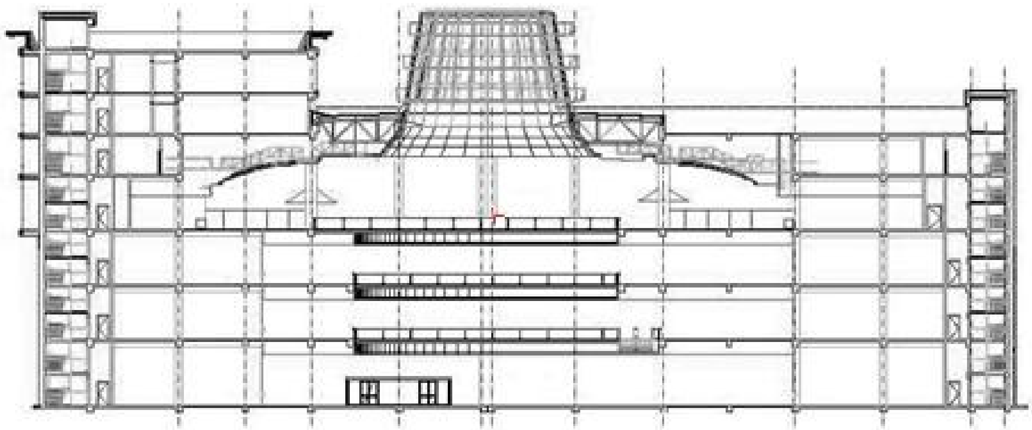


Figure 3.6. The cross-section of CEPA Shopping Center.

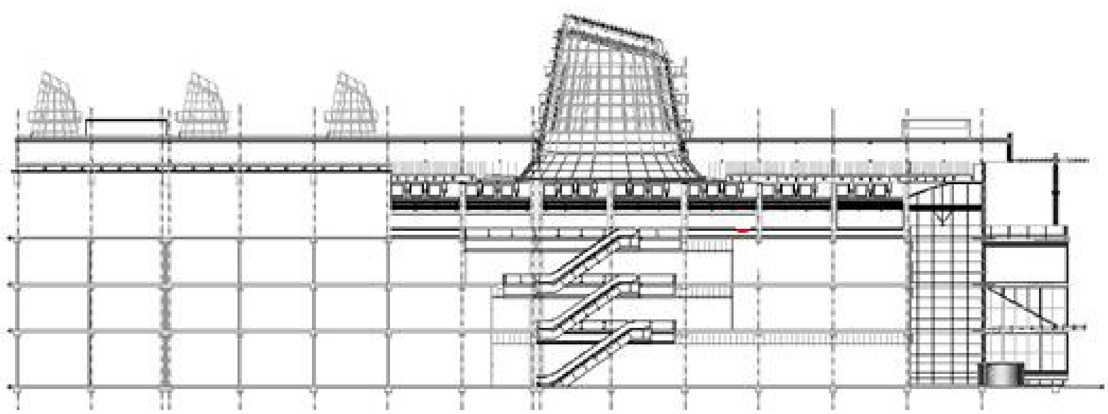
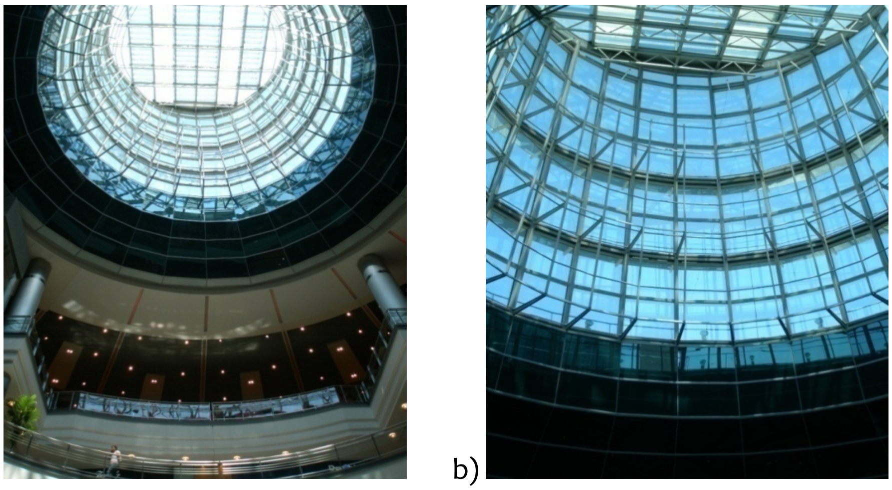


Figure 3.7. The longitudinal section of CEPA Shopping Center.

The food court area is the circular enclosed space that is surrounded by various restaurants and cafes at the sides and a glass dome ceiling above. The considered volume of the food court area is approximately 30,000 m^3. The atrium is located at the middle of the space with a circular opening which provides visual and audile connection with the overall shopping area (see Figure 3.7 and 3.9).



a) b)

Figure 3.8. a) Glass dome ceiling located at the center of the atrium void and b) the details of the dome structure.

3.5.2. Materials and Applications

In CEPA Shopping Center, there is no significant intervention for obtaining better acoustical conditions regarding materials except the food court ceiling, which is covered by longitudinal strips of vertical plaster panels. These vertical strips prevent reflections from the ceiling, acting as scatters or absorbers for the sound waves. The other materials which are large panes of glass used on the dome skylight (see Figure 3.8), wide glass shop cases, granite for the finishing material on floors and aluminum cladding of the columns are all act as reflectors for certain frequencies that leads to the formation of the negatively effective acoustical parameters. The chosen materials and their application in CEPA Shopping center are found to be non-effective regarding the acoustical formations in the space. Instead, absorptive materials and surfaces are essential for controlling the unwanted and excessive noise or vibration.

Figure 3.9. The overall food court area with the atrium void and glass dome ceiling.

4. OBJECTIVE AND SUBJECTIVE EVALUATIONS ON FOOD COURT OF CEPA SHOPPING CENTER

4.1. Computer Simulation Results

The computer simulations for this study are done by ODEON 6.5 Room .The software is used to analyze acoustical characteristics of the food court area. Reverberation Time (RT), Early Decay Time (EDT), Sound Transmission Index (STI) and Sound Pressure Level (SPL) are simulated (Dökmeci, Yılmazer, Çalışkan, Erkip, 2008).

The position of the source is set to the points, X: 1595m, Y: 820m and Z: 28m as designated with a pink circle and the receiver on the points, X: 1632m, Y: 822m and Z: 28m as designated with a blue circle in Figures 4.1., 4.2., and 4.3. The source is defined to be an omni-directional one and the overall gain is assigned as 90 dB.

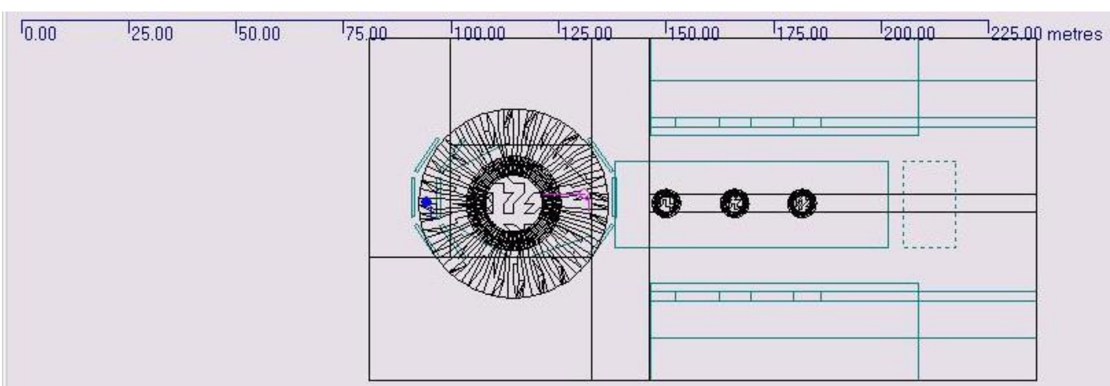


Figure 4.1. Plan of CEPA Shopping Center showing source and receiver positions from the computer simulation.

The source type, gain, directivity pattern, equalization and delay are also set. The receiver is identified as surface receiver with 1.2 meters of height and grids of 5 meters.

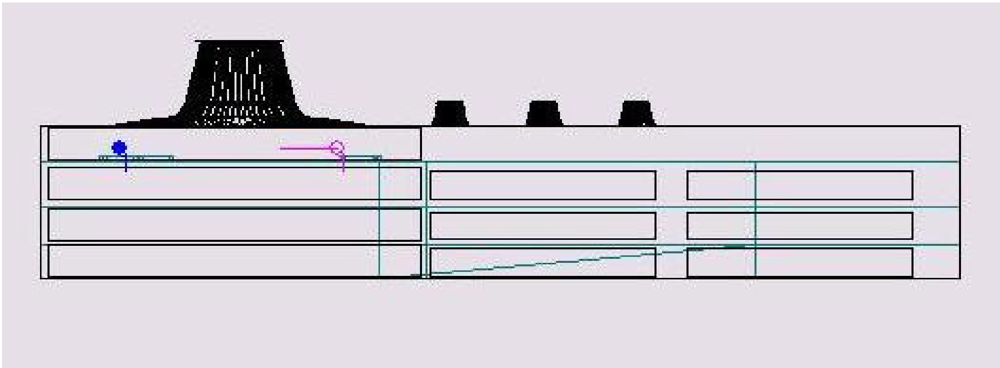


Figure 4.2. Longitudinal section of CEPA Shopping Center showing source and receiver positions from the computer simulation.

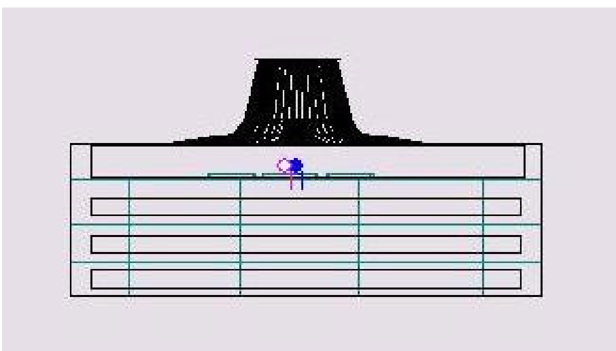


Figure 4.3. Cross-section of CEPA Shopping Center showing source and receiver positions from the computer simulation.

The current finishing materials present in food court area of CEPA Shopping Center are used in the simulated model of CEPA and given in Table 4.1. The results of the simulations showed that there is a very less material absorption obtained by the current materials in the case space. Figure 4.4 show that the overall volume and the air within the space act as the main absorber for frequencies over 2000 Hz. Yet, the other materials such as empty chairs upholstered by cloth cover acts as the major absorber at all frequencies when compared to other materials in the space (see Figure 4.5).

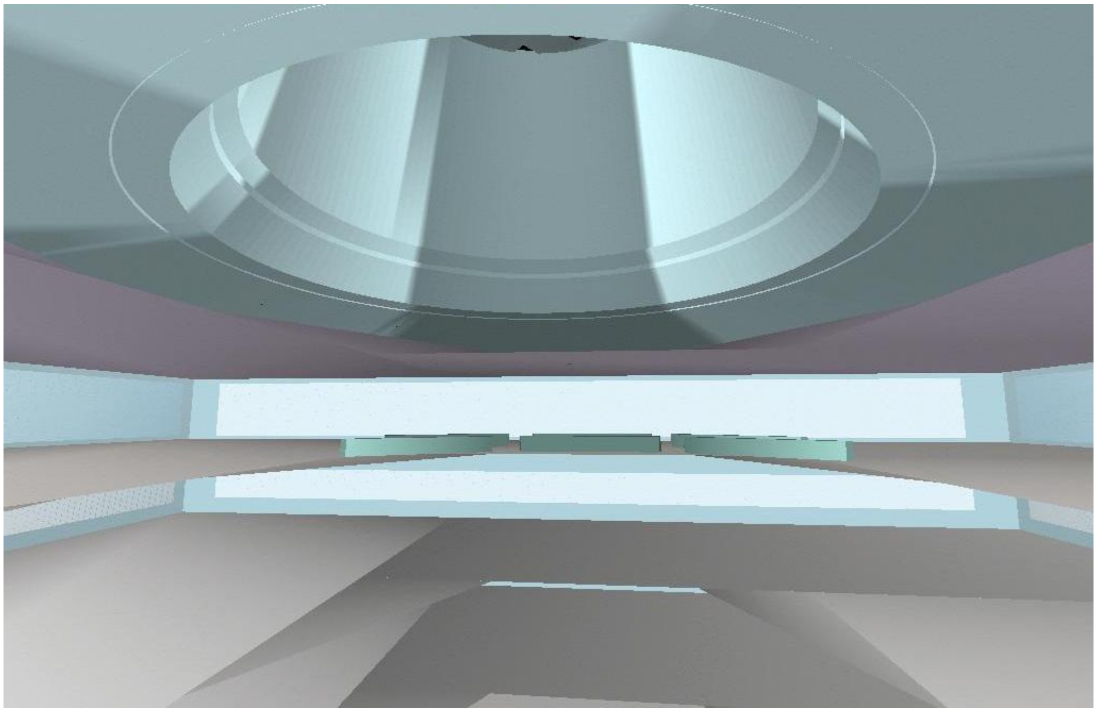


Figure 4.4. 3D view of the model as seen from the source.

Table 4.1. Material list and sound absorption coefficients used for the model.

Surface	Material	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz	Scattering Coefficient
Dome	Large panes of heavy plate glass*	0.18	0.18	0.06	0.04	0.03	0.02	0.02	0.02	0.1
Ceiling	Plasterboard on battens with large air-space above	0.2	0.2	0.15	0.1	0.08	0.04	0.02	0.02	0.3
Walls	Gypsum board, 2 layers 32mm	0.28	0.28	0.12	0.1	0.17	0.13	0.09	0.09	0.1
Floors	Marble or glazed tile*	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.1
Kiosk panels	Acrylic with 10cm air-space	0.1	0.4	0.2	0.1	0.1	0.05	0.05	0.05	0.1

Showcase windows	Ordinary window glass*	0.35	0.35	0.25	0.18	0.12	0.07	0.04	0.04	0.1
Wood Separation units	Veneered wood cladding	0.4	0.3	0.2	0.17	0.15	0.1	0.21	0.21	0.1
Windows	Double-glazing 2-3 mm glass, 10mm gab	0,1	0,1	0,07	0,05	0,03	0,02	0,02	0,02	0.1
Restaurant part	Empty chairs upholstered by cloth cover	0,44	0,44	0,6	0,77	0,89	0,82	0,7	0,7	0.2
Food court area	Chair, metal or wood-unoccupied	0,02	0,02	0,02	0,03	0,04	0,04	0,05	0,05	0.2

Note. * Ref. Harris Handbook of Acoustical Measurements and Noise Control.

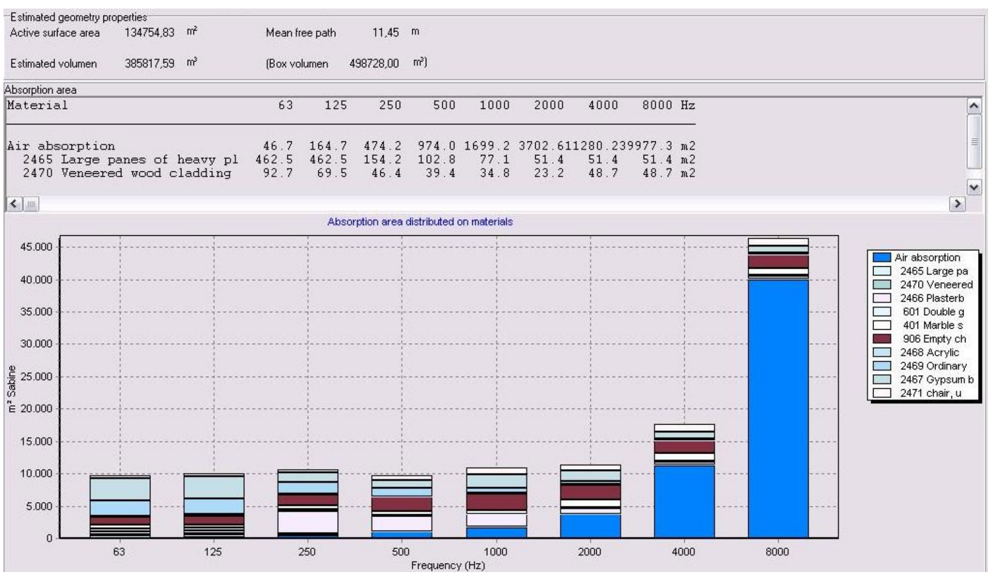


Figure 4.5. Bar chart showing the total absorption area of current materials assigned for the computer simulation.

4.1.1. Reverberation Time (RT)

Kang (2002) notes that increased seat density and occupancy are effective for decrease on EDT and RT values in dining spaces. For this study such a comparison is not researched and the decay time simulations are take place with unoccupied situation. The quick estimate tool that derives the results of the Sabine reverberation times according to the material absorption coefficients of the computer simulation, given in Figure 4.6 shows that, the Sabine reverberation times vary between 6.5 seconds and 1 second, which are similar with the simulated results.

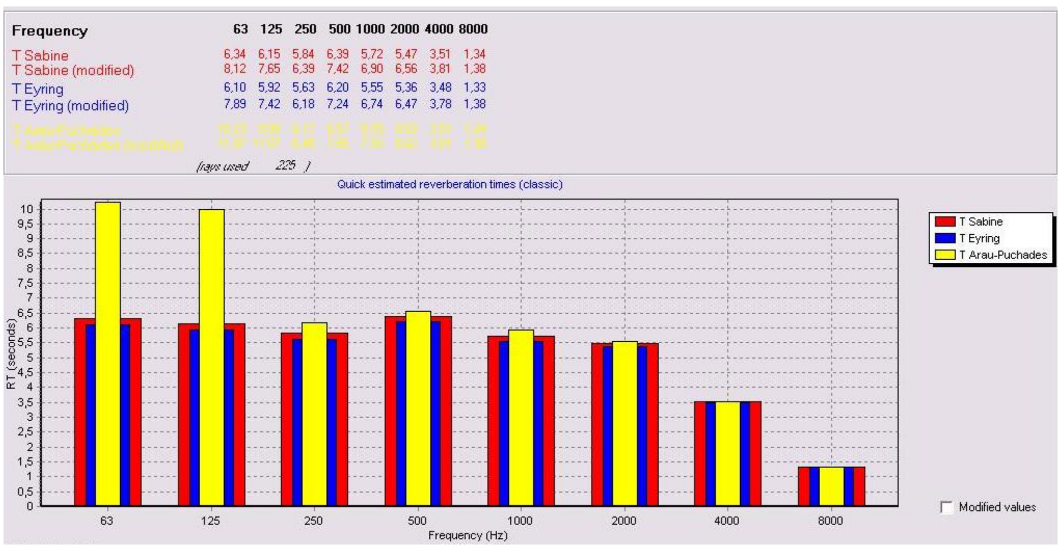


Figure 4.6. Estimated global reverberation times of Sabine, Eyring and Arau-Punchades derived by material properties.

Figure 4.7 gives estimated global reverberation times of T30 and T20 for varying frequencies between 63 Hz and 8000 Hz. It can be seen that T20 values are given to be lower by 0.5 to 2 seconds when compared to T30s. Yet, both values are show decrease with increasing frequency and vary between 11 seconds and 1.5 seconds. Cumulative distribution function graph of T30 at 1000 Hz and T30 free path distribution and

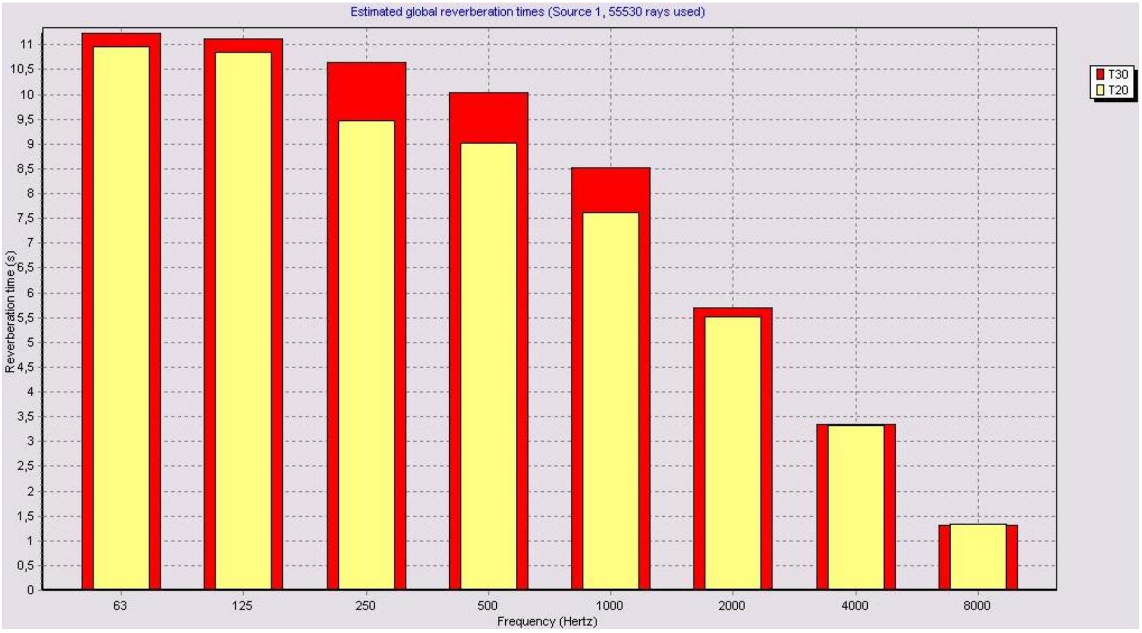


Figure 4.7. Bar chart showing the estimated global reverberation times of T30 and T20.

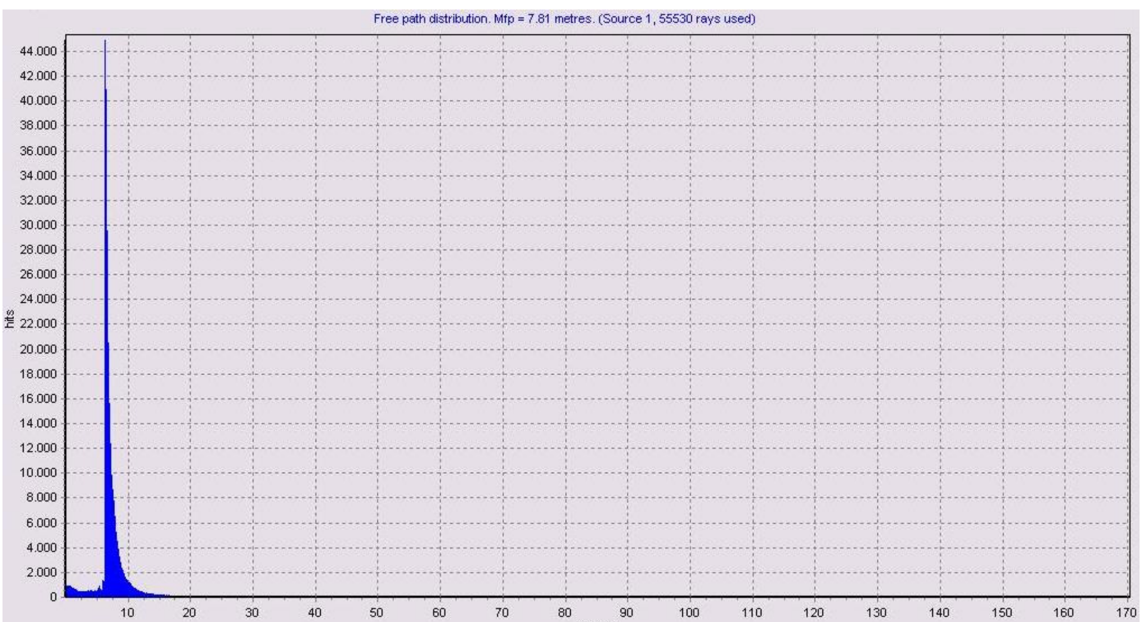


Figure 4.8. Free path distribution map.

Figure 4.9. Cumulative distribution function graph of T30 at 1000 Hz.

Figure 4.9 shows the distribution map for the reverberation time at 1000 hertz. The decay time value of T30 is given to be 5.10 seconds for 1000 Hz. It can be seen from the map that longer reverberation occurs near the atrium, under the glass dome ceiling. Yet, the reverberation time is plotted to be shorter on the areas far from the fast food kiosks, and glass dome ceiling. One other reason is the increase on the seat area with cushioned armchair in the rare part of the space.

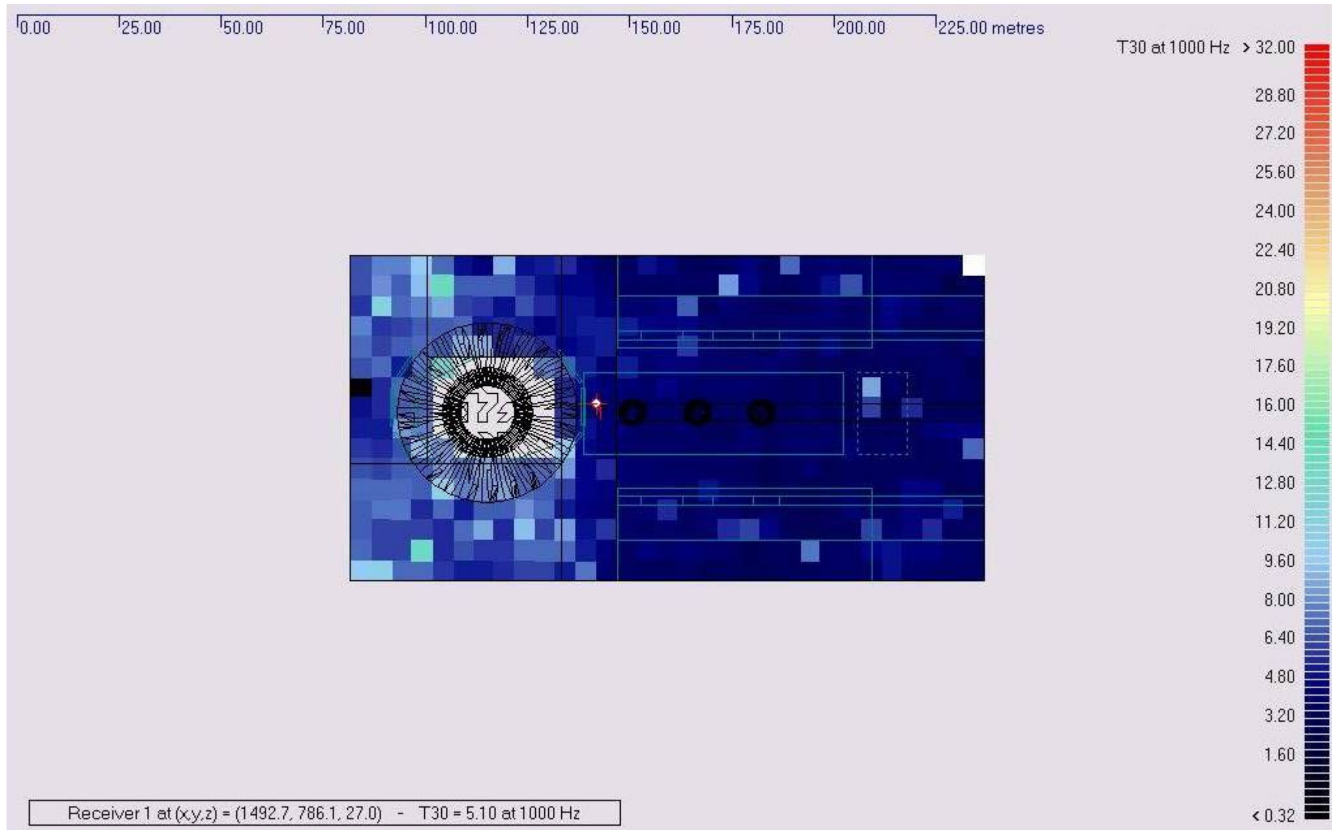


Figure 4.10. T30 distribution map for 1000 Hz.

4.1.2. Early Decay Time (EDT)

The distribution maps are given for 1000 Hz range as it is the critical frequency range for both hearing and speech. Cumulative distribution function graph of EDT at 1000 Hz is given in Figure 4.11. The early decay time for 1000 Hz is given to be 3.38 seconds by the simulation (see Figure 4.12). 3.38 seconds for early decay time of a sound at 1000 Hz is found to be very long.

Figure 4.11. Cumulative distribution function graph of EDT at 1000 Hz.

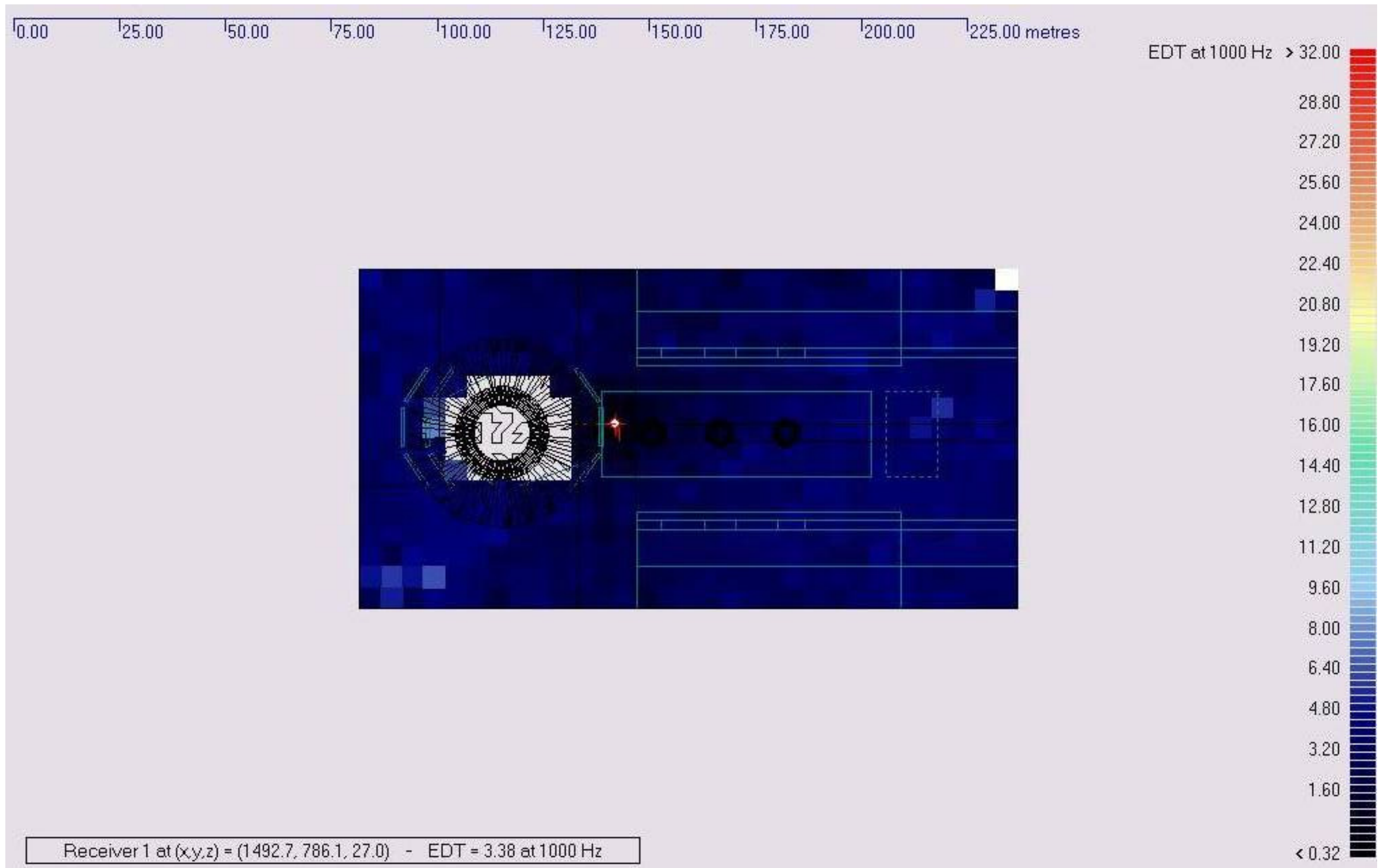


Figure 4.12. EDT distribution map for 1000 Hz.

The decay times (T30 reverberation time and early decay time) obtained by the simulations are given in Table 4.2 and their relation can be seen in Figure 4.13. As given in the table, the results vary for low and high frequencies. 63 and 125 Hz are the frequencies that are simulated to be longest. There is a sudden drop for 250 Hz, yet a 1 second increase for the following range.

Table 4.2. Simulated RT and EDT values for 63-8000 Hz frequency range.

	63 Hz	**125 Hz**	**250 Hz**	**500 Hz**	**1000 Hz**	**2000 Hz**	**4000 Hz**	**8000 Hz**
T30 (sec.)	10.9	10.6	4.6	6.2	5.1	5	3	1.2
EDT (sec.)	8.6	8.4	2.5	3.5	3.4	4	2.5	1.5

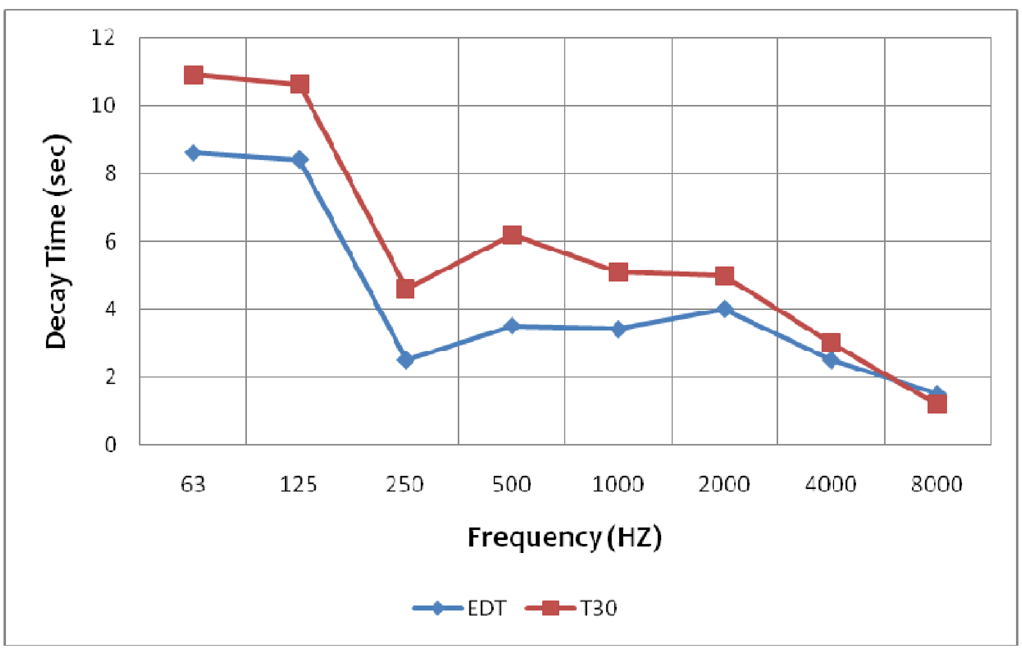


Figure 4.13. Graph showing RT and EDT results of simulation for 63-8000 frequency range.

4.1.3. Speech Transmission Index (STI)

The speech transmission index values are obtained by the simulation program with the grid response option and the value is obtained to be 0.37 (see Figure 4.14). Such a value is rated as poor as mentioned before in Table 2.1. As it is previously stated in Section 2.1.4, EDT values are found to be well related with STI value (Chen, Kang, 2004). Kang (2002) also mentions that STI is directly related with shape of the room, seat density and absorber arrangements in a dining space.

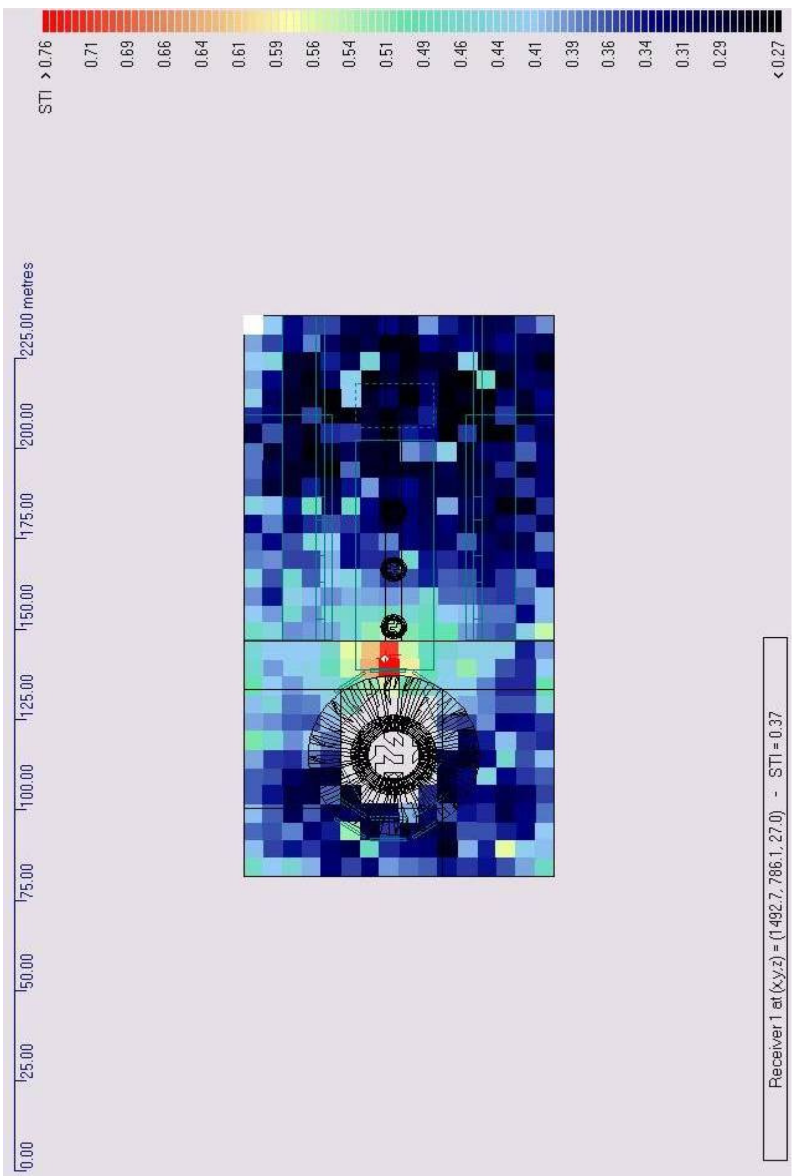


Figure 4.14. STI distribution map.

4.1.4. Sound Pressure Level (SPL) and A-weighted Sound Pressure Level (SPL-A)

The simulation also predicts upon the expected sound pressure level distributions for the given frequency range. Figure 4.15 gives the distribution map of SPL level for 1000 Hz. The gain of the sources 90dB and the results of the sound pressure levels are given in Table 4.3 the sound pressure levels are getting lower by the higher frequencies.

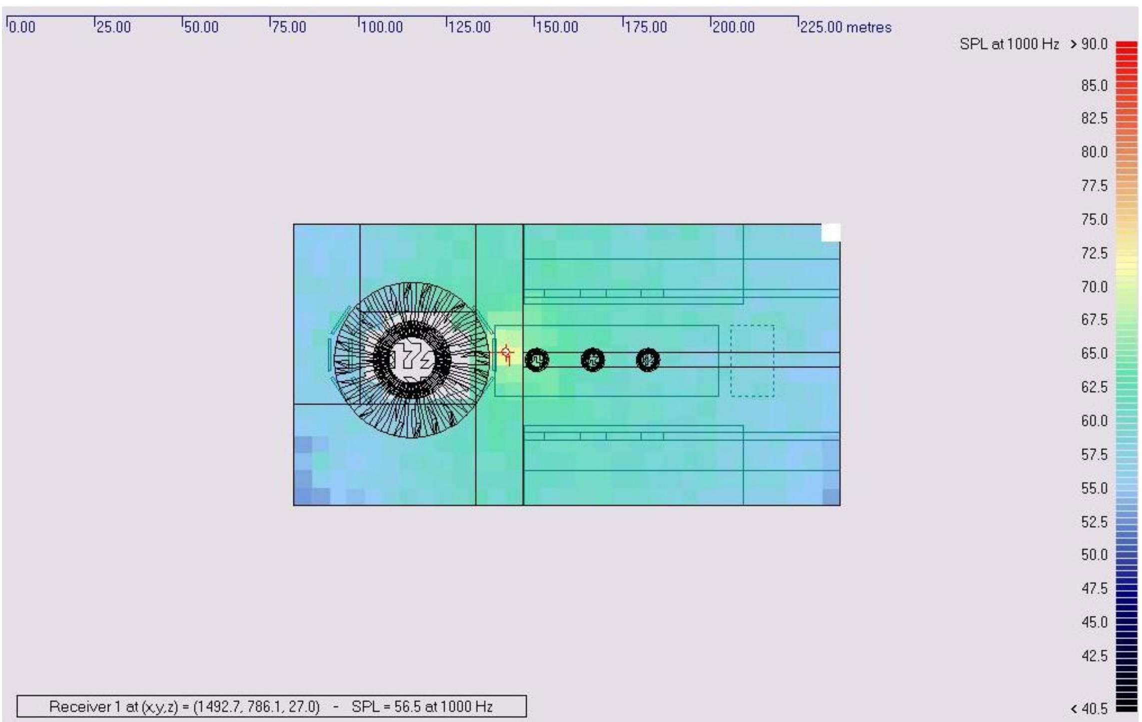


Figure 4.15. SPL distribution map for 1000 Hz.

Table 4.3. Simulated SPL values for 63-8000 frequency range.

	63	125	250	500	1000	2000	4000	8000
SPL	60,5	60,6	55,6	56,9	56,5	57,3	53,8	42,1

The A-weighted sound pressure level of the space has been given by the simulations as 62.5 dBA (see Figure 4.16). The distribution map of A-weighted sound pressure level and speech transmission index seem to be well correlated when compared with other parameters considered in the simulation. The main reason for these distributions to occur as given in figures 4.14 and 4.16 is the source location. As it can be seen in these figures, source location and the near area is plotted worse for SPL (A) levels and STI classifications.

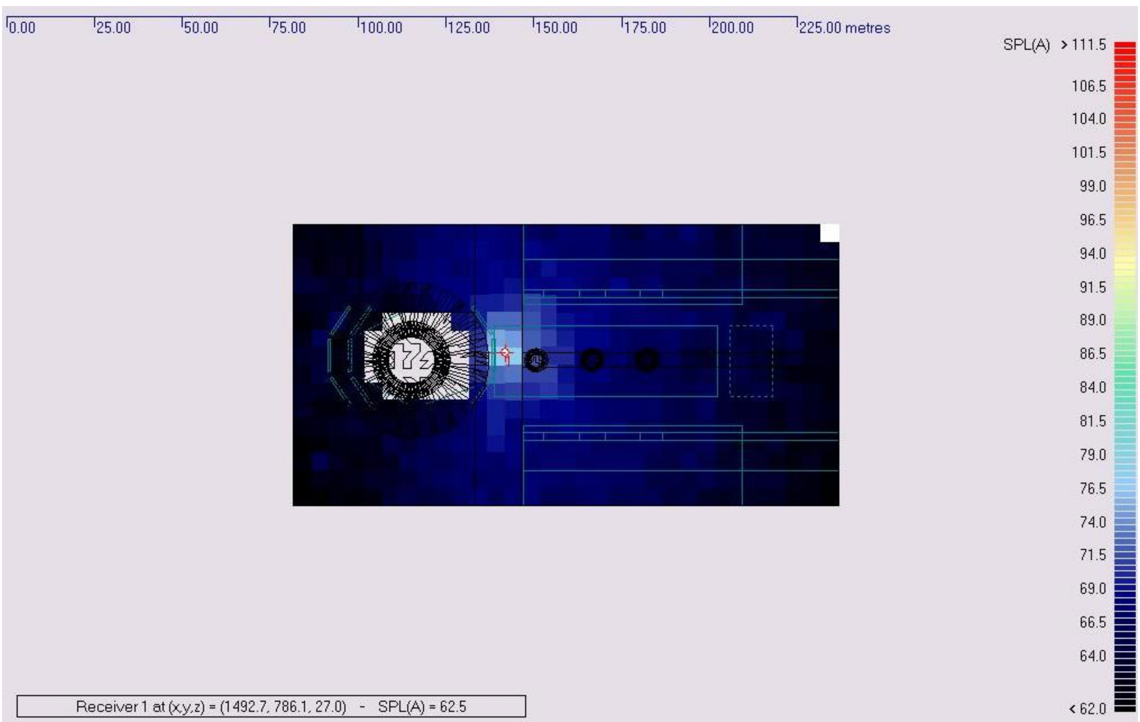


Figure 4.16. SPL (A) distribution map.

4.2. Noise Measurements

The noise measurements are done at the third floor where the food court area is located. Measurements are done at three identified locations for each time slots. As seen in Figure 4.17, the first measurement location is near the atrium (m1) at the symmetry axis of the space. The second measurement location (m2) is 10 meters away from the atrium on the same axis and the third location (m3) is 20 meters away from the atrium at the same axis.

A total of twenty-one measurements are made for each day type for determining the Leq values. All Leq values are obtained by one-minute averaged measurement technique done by Dirac 3.0 room acoustics software and Bruel & Kjaer type 2230 sound level meter.

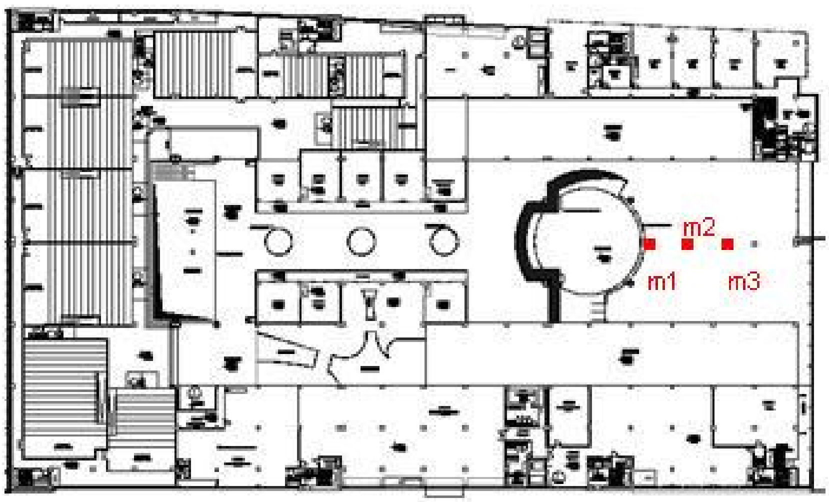


Figure 4.17. Food court plan showing the Leq measurement points.

Measurements are done in two different day types as weekdays and weekends during one week. Each day is divided into four time slots as; morning (10:00), noon (12:00-14:00), afternoon (16:00-18:00), and evening (20:00-22:00). Measurements are done between 10:00 to 22:00 with two hour intervals having a total of seven measurement times (10:00, 12:00, 14:00, 16:00, 18:00, 20:00, and 22:00).

4.2.1. Results of Equivalent Continuous Sound Pressure Level (Leq) Measurements

Background noise is measured in the food court space when the shopping center is closed to users. The Leq value of the unoccupied space is found to be 44 dBA. So, this sound pressure level gives the value of HVAC noise and the noise coming from outdoor environment and also present during the occupied conditions of the shopping center.

The Leq values for the weekdays and the weekends are obtained by measurements done during seven time slots for each day type (weekdays and weekends) during one week period. The mean values obtained for different time slots on the weekdays are noted as seen in Table 4.4. The mean Leq values of weekends are quite different from that of the weekdays. The mean Leq value measured at weekends is 68.3, which is approximately 5 dBA higher than the weekday total mean Leq value (see Figure 4.18).

Table 4.4. Measured Leq values at different times during weekdays (WD) and weekends (WE).

	Morning		**Noon**		**Afternoon**		**Evening**		**Averaged**	
	Mean	STD(σ)	Mean	STD(σ)	Mean	STD(σ)	Mean	STD(σ)	Mean	STD(σ)
Weekdays Leq (dBA)	57.9	1.14	63.3	2.19	64.8	0.7	65.4	3.26	63.5	3.23
Weekends Leq (dBA)	65.1	0.36	69.2	1.74	71	1.39	66.4	1.78	68.3	2.51

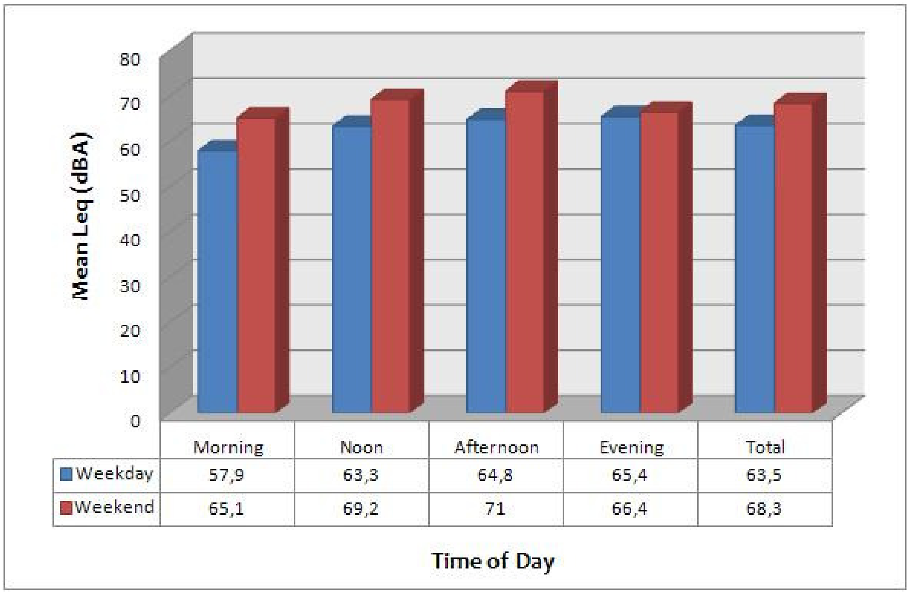
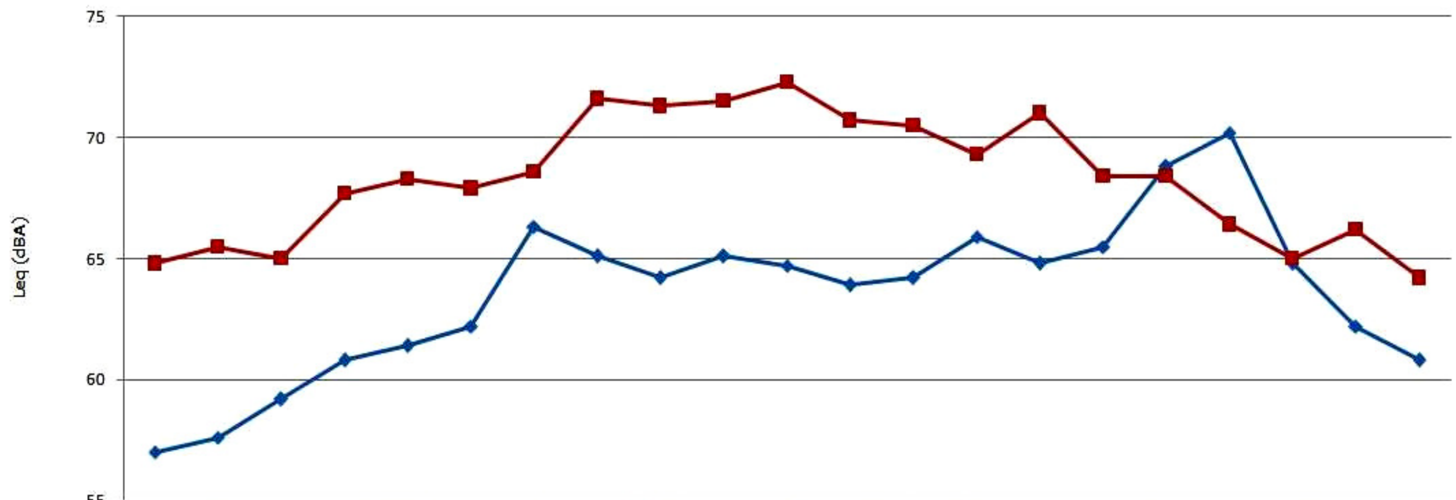


Figure 4.18. Mean Leq values for weekends and weekdays of different hours.

In Figure 4.19, the Leq variations on different time slots and measurement locations are given, in order to present the Leq differences between weekdays and weekends. As, it can be plotted from the figure, the highest separated Leq value peaks are obtained during noon and evening at weekdays. Yet, the weekends show smoother variations all through the day, with higher slope during noon and afternoon.



	10:00 Atrium	10:00 A+10m	10:00 A+20m	12:00 Atrium	12:00 A+10m	12:00 A+20m	14:00 Atrium	14:00 A+10m	14:00 A+20m	16:00 Atrium	16:00 A+10m	16:00 A+20m	18:00 Atrium	18:00 A+10m	18:00 A+20m	20:00 Atrium	20:00 A+10m	20:00 A+20m	22:00 Atrium	22:00 A+10m	22:00 A+20m
Leq-WD	57	57,6	59,2	60,8	61,4	62,2	66,3	65,1	64,2	65,1	64,7	63,9	64,2	65,9	64,8	65,5	68,8	70,2	64,8	62,2	60,8
Leq-WE	64,8	65,5	65	67,7	68,3	67,9	68,6	71,6	71,3	71,5	72,3	70,7	70,5	69,3	71	68,4	68,4	66,4	65	66,2	64,2

Figure 4.19. Measured Leq values for weekends (WE) and weekdays (WD) of different hours and locations.

4.2.2. Sound Pressure Level (SPL-A) Variances for Different Frequencies

The averaged SPL (A) values are given in the Figure 4.20. As it can be seen the averaged values for weekends are higher than the ones on weekdays. In addition, for both day types the peak values are obtained for the mid-frequencies that are 500 Hz and 1000 Hz. The most important range for human ear is 4000 Hz as the wavelength of this frequency range well-matches with the ear tunnel length resulting in the highest annoyance. Yet, for intelligibility of the sounds, 125 Hz and 8000 Hz are crucial. Vowels within the range of 125-2000 Hz and consonants are within the range of 2000-8000 Hz range (Long, 2006). The most important frequency range is between 250 to 2000 Hz for speaking and intelligibility. Yet, the values show increase for these frequency ranges as a result of the noise present in the space which can be classified mostly as the speech noise from the users of the food court. More detailed information regarding the differing SPL (A) values for varied locations both on weekends and weekdays are given in Table 4.5 and 4.6.

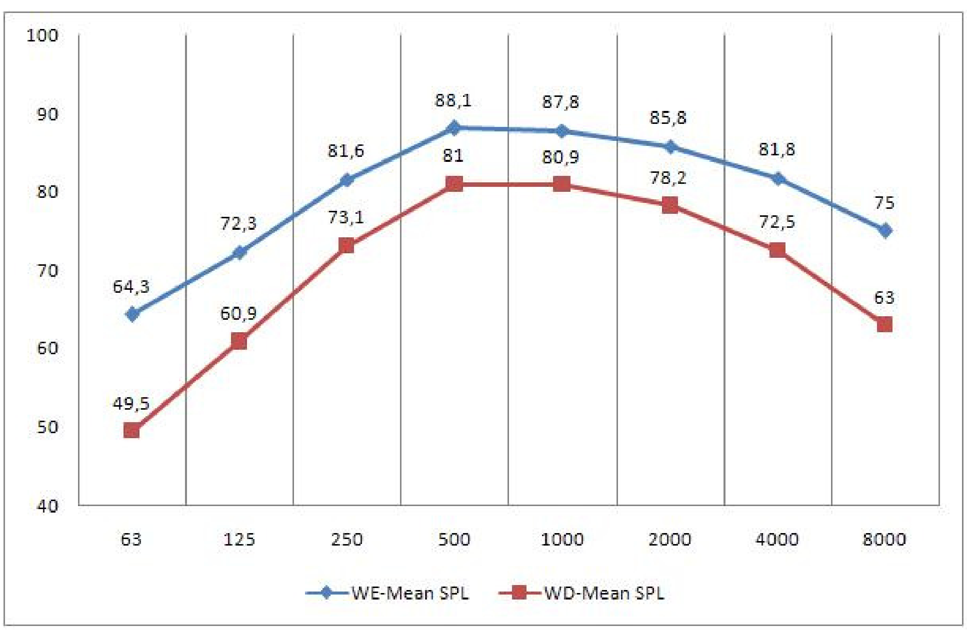


Figure 4.20. Averaged SPL-A level changes for different frequencies between 63-8000 HZ.

Table 4.5. Differing SPL-A values measured on specified locations on weekends

Different Measurement Locations	63	125	250	500	1000	2000	4000	8000	Averaged
10A	41,1	54,7	68,9	77,5	76,9	74,2	67,6	56,9	64,7
10A+10	39,4	54,7	67,5	76,6	77,3	74,1	66,6	55,1	63,9
10A+20	41	54,8	67,2	74,9	74,7	71,2	66	55,1	63,1
12A	46,7	58,8	72,2	80,1	79,9	76,5	69,8	59,5	67,9
12A+10	48,5	60,7	74,7	81,5	81,9	79,7	74,1	64,3	70,6
12A+20	50,8	59,4	71,5	80,2	80,4	78,5	72,1	61,2	69,26
14A	46	57,8	71,5	80,6	80,6	76,9	70,3	59,8	67,9
14A+10	65,6	73,2	82	89,4	88,1	85,9	82,3	76,6	80,3
14A+20	64,3	72,9	81,8	88,7	87,8	85,9	82,3	75,9	79,9
16A	66,4	73,9	82,1	89,7	88,1	86,3	82,7	76,7	80,7
16A+10	66	73,8	82,3	89,4	88,3	85,7	81,8	75,5	80,3
16A+20	64,4	73,2	81,9	88,6	88,2	85,8	81,3	74,6	79,7
18A	44	57,3	71,7	79,4	79,5	76,4	70,5	60,6	67,4
18A+10	43,2	56,7	70,8	79,7	79,9	76,4	70,1	60,1	67,1
18A+20	49,3	60,4	73	83	82,4	78,8	72,1	61,5	70,0
20A	47,1	57,8	72,4	80,6	82,8	78,8	72,8	61,8	69,2
20A+10	43,6	58,2	70,5	81,3	81	77,5	70,9	61,1	68,0
20A+20	47,2	58,6	70,9	79,5	79,6	76,2	69,8	57,9	67,4
22A	40,4	55,1	68,2	74,8	75,6	73	67,3	56,8	63,9
22A+10	43,3	53,8	66,3	73,8	73,9	71,6	66,8	56	63,1
22A+20	42	52,4	67,2	72,7	71,9	72,5	66	55,8	62,5

Frequency (Hertz) — **Measured SPL-A Values on Weekends**

Table 4.6. Differing SPL-A values measured on specified locations on weekdays

Different Measurement Locations	63	125	250	500	1000	2000	4000	8000	Averaged
10A	64	72,9	80,9	86	86,5	84,2	80,1	71,7	78,2
10A+10	62,9	71	81,2	86	86,6	83,9	80	71,5	77,8
10A+20	62,4	71,5	80,7	86,7	86	84,3	79,5	70,2	77,6
12A	65,5	71,9	80,7	87,8	87,9	87	82	75,2	79,7
12A+10	63,6	72,4	81,8	88,2	87	85,3	81,2	73,8	79,1
12A+20	64,1	71,8	80,4	87,7	88	86,1	82,6	75,4	79,5
14A	67	73,6	82,6	89,1	88,4	86,6	82,8	77,4	80,9
14A+10	64,7	72,6	83,2	88,6	87,9	86	82,1	76,2	80,1
14A+20	64,5	73,2	82,9	88,2	88	86,1	81,9	75,5	80,0

Frequency (Hertz)

16A	64,5	71,9	81,5	88,6	88,6	86	81,9	75,6	79,8
16A+10	64,5	72,2	81,1	88,3	88,7	86,5	82,6	76,6	80,0
16A+20	64,5	72,4	82	88,3	88,7	86,2	82,1	75,7	79,9
18A	64,4	72	81,7	88,8	88,1	85,7	81,4	74,8	79,6
18A+10	64,1	72,3	81,2	87,6	88,6	86,7	82,8	76,7	80,0
18A+20	64	72,8	81,9	88,8	87,7	86,5	81,5	74,7	79,7
20A	63,9	72,4	82,6	88,4	87,3	85,8	82,3	76,5	79,9
20A+10	66	73,2	82	89,5	88	86,1	82,6	77,2	80,5
20A+20	65	72,8	81,8	88,7	88,6	85,9	82	76	80,1
22A	63,3	71,9	81,4	88	87,4	85,8	82,7	75,8	79,5
22A+10	64,1	72,2	81,6	89	87,9	85,7	81,6	74,2	79,5
22A+20	63,4	71,3	81,6	87,3	87,6	86	82,4	75,3	79,3

Measured SPL-A Values on Weekdays

4.3. Questionnaire Results

Through the case study done in food court area of CEPA Shopping Center, the subjective evaluation and statistical analysis of a sample group of two hundred and forty (240) people is presented and discussed regarding overall demographics, user's space utilization, noise annoyance and auditory perception for different sound sources on different days, and in different time slots in food court area and in CEPA Shopping Center.

4.3.1 Demographics and User's Space Utilization Characteristics

The sample group consisted of 128 males and 112 females are classified into four groups according to their education level. These are given in Figure 4.21 with their education levels in percentages as, primary school, high school, university or university student, and master's, PhD degree. The distribution of the questionnaires according to the visiting day (weekdays, weekends) was done evenly being 50-50% that is 120-120 people division. The age distribution is also given in Table 4.7.

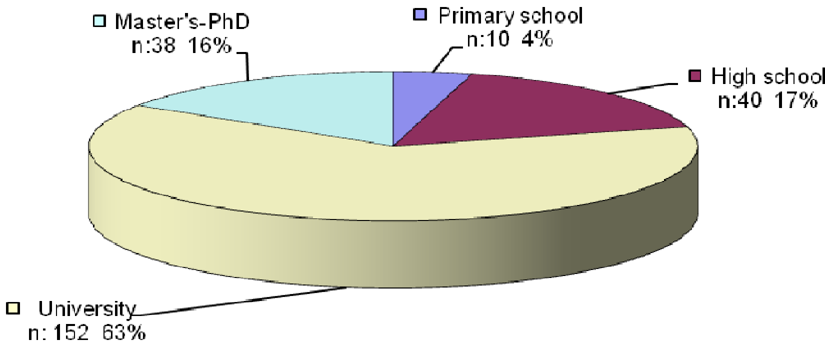


Figure 4.21. Distribution on the education level.

Table 4.7. Age distribution of the sample group.

Age Interval (yrs)	Frequency (n)	Percentage (%)
20-35	141	58,8
36-50	51	21,3
51-65	48	20,0
Total	240	100

Majority of the users (68.8 %) noted that they prefer to stay in the food court area for the purpose of conversation and other activities. The rest of the users (31.3%) noted that they do not prefer to stay for conversation, yet they still use the food court area for eating, drinking, or reading. The Mann-Whitney U test shows that there is no significant correlation between preferred activity (category 1: any activity and conversation, category 2: any activity other than conversation) in the food court and annoyance from other people (U=5417.000, p=0.108).

4.3.2 Noise Annoyance Ratings and Auditory Perception

In order to obtain a general knowledge on the annoyance ratings of the sample group, two basic questions regarding annoyance during eating and during conversation in a noisy environment in general is asked. These two questions give information about the users understanding of noise annoyance. Kendall's Tau-c coefficients test shows that (see Appendix C, Table C1.1), noise annoyance during eating and noise annoyance during conversation are significantly correlated with each other (τ_c =0.459, df=4,4, p<0.001). This shows that the user group tends to be annoyed at the same rate for the activities of eating and conversation in a noisy environment.

The noise annoyance ratings done on a 5-scale show that 89.9 percent of the subjects find the food court area to be noisy (intermediate-3 + noisy-4 + very noisy-5) (see Figure 4.22).

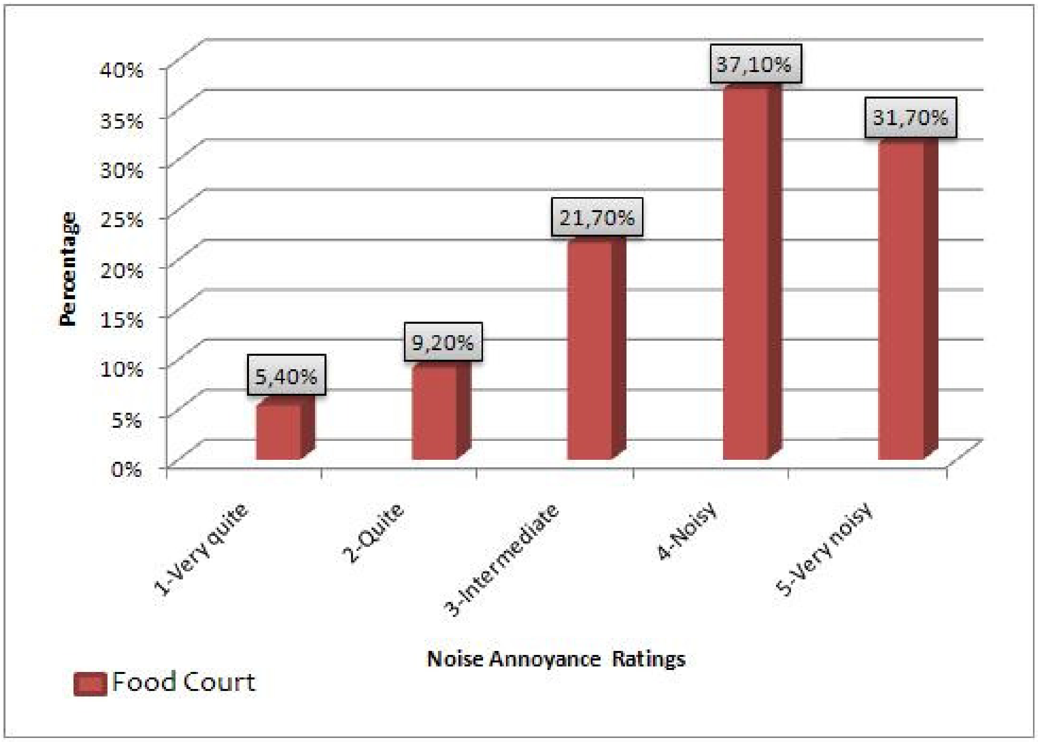


Figure 4.22. Noise annoyance ratings in food court.

4.3.3 Response to Different Sound Sources

The questionnaire also included questions on the type of sounds that the subjects are hearing while they were filling out the survey. The most annoying sound and the most dominantly heard sound are asked separately and the outcomes show variances that gives clues on the auditory perception of the users. The question on the most dominantly perceived sound does not imply any annoyance, so the answers on that particular question are not discussed as annoyance classification. Although, in the case of auditory perception, most annoying and most dominant sound may imply differing meaning, the results states that in many cases (different day types and time slots) most dominantly perceived sound is also noted as the most annoying sound.

Pearson's Chi-Square test is used to find the correlation between the defined most dominantly perceived sound type such as; speech noise, hum of voices, and chairs scraping and the defined most annoying sound type of the users (see Appendix C, Table C1.2). The result shows that there is a positive significant correlation between two variables (χ^2=75.4, df=4,3, p<0.001). The two questions are open-ended and the categories are derived from the answers given by the users. This correlation can be interpreted as; the users tend to dominantly perceive the sound that they get highly annoyed. In addition, especially for this case being a crowded food court of a shopping center, speech noise is found to be both the most dominantly perceived and the most annoyed sound.

4.3.4 Noise Annoyance Rating Variations on Weekdays and Weekends

The descriptive analysis show that weekends have higher noise annoyance ratings when compared to weekdays for the categories, annoyance from the overall noise in CEPA and noise annoyance from other people in food court (see Table 4.8). When the correlation results obtained by Mann-Whitney U test (see Appendix C, Table C1.3) are considered, a significant correlation is present between annoyance from overall noise in CEPA for the food court users at weekdays and at weekends (U=5929.000, p=0.012). Yet, there is not a significant correlation between noise annoyance from other people in food court at weekdays and at weekends (U=6276.000, p=0.074).

Table 4.8. User's noise annoyance ratings for weekdays and weekends.

		Mean value of noise annoyance rating	Median value of noise annoyance rating
Weekdays	Annoyance from overall noise in CEPA	3.38	3
	Noise annoyance from other people in food court	3.63	4
Weekends	Annoyance from overall noise in CEPA	3.68	4
	Noise annoyance from other people in food court	3.88	4

There found to be no significant correlation between noise annoyance from other people in the food court at the weekdays noon and at the weekends noon (U=761.000, p=0.691) or at the weekdays evening and at the weekends evening (U=631.000, p=0.093). It can be explained that, during lunch and dinner time periods the speech annoyance in the food court is not very significant regarding weekdays or weekends. Yet, there is a significant correlation between noise annoyance from other people in the food court at the weekdays afternoon and at the weekends afternoon (U=552.500, $p<0.05$) (see Appendix, Table C1.4). These results imply that, the annoyance ratings of the users from speech noise in the food court during the afternoons greatly vary on the day type.

4.3.5. Time Spent Preferences and Noise Annoyance Ratings in the Food Court

Although people tend to do many activities at once, the estimated time spent in the food court is reported as '1-2 hours' by the majority of the users (94%) (see Figure 4.23). Few users (6%) noted the time spent in food court area as '3-4 hours' or '>4 hours'. One other interesting relation that is tried to be defined is between noise annoyance and time spent (see Appendix C, Table C1.5). The results of Kruskal-Wallis one-way ANOVA test shows that there is a significant positive correlation between noise annoyance from other people in food court and time spent in food court (χ^2=7.904, df=2,1, p=0.019).

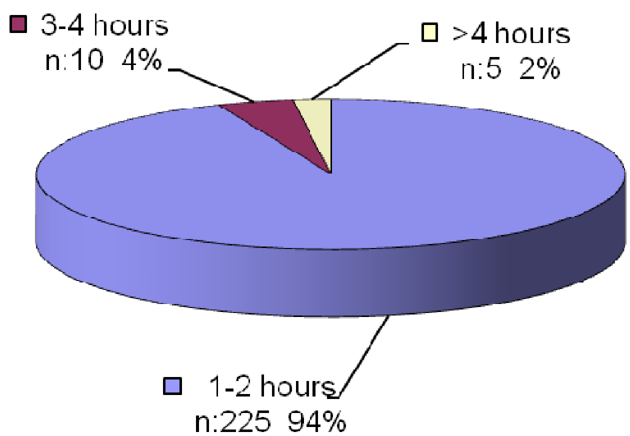


Figure 4.23. Distribution of users according to the time spent in food court.

5. DISCUSSION

Computer simulations are done to put forth the acoustical characteristics of the space, in addition noise measurements are carried out to assess the a-weighted sound pressure level that the users are exposed during one day period on weekdays and on weekends. Questionnaires are the final step for addressing the users' noise annoyance ratings and auditory perception. The two approaches are discussed under the topics; analyzing the acoustical characteristics of the food court in CEPA and relationship between Leq measurements and noise annoyance ratings.

5.1. Analyzing the Acoustical Characteristics of the Food Court in CEPA

In the simulation results of CEPA, the early decay time and reverberation times are considered and found to be very long and quite different from each other. It has been noted in the literature that, atriums feature rather long reverberation times at all frequencies (Chen, and Kang, 2004). Yet, 5.10 seconds at 1000 Hz of CEPA is not a preferred RT values for any public space. The reason of such long decay times could occur as the result of the highly reflective surfaces present in the space and the large volume considered for the simulation. The present architectural features such as the glass dome ceiling and the central atrium in addition with the corridor like back circulation area of the shopping center are as well very effective for such decay characteristic of the sound.

Although Bradley (1998) states that the early decay times are ideally 0.1 seconds lower than the reverberation times at mid frequencies and larger differences for lower frequencies in an enclosed space, the differences for EDT and RT value differences are changing between 2.7 seconds and 1 second for mid frequencies (500-1000-2000 Hz) in this study. In addition, the EDT values are nearly 35% lower than the RT values for 1000 Hz. So, a desired relation has not been obtained for most of the frequency ranges for this study, both EDT and RT values are not well relates with each other forming a highly reverberant and non-diffused field. These decay characteristics of the space leads to poor speech transmission index that are also supported by the simulation findings of CEPA Shopping Center.

Similarly with the distribution maps of reverberation times, early decay time maps for 500 and 1000 Hz seem to be very similar with each other. Although, both maps looks very similar the crucial part is the distribution plot near the atrium void. There is longer early decay time near the atrium void than the areas that are not directly linked with the void. The reason for such a plot can be explained with the study of Chen and Kang (2004) in Meadowhall Shopping Center. They have also concluded that the atrium void is the primary reason for longer reverberation for all frequency ranges. In their study, the lowest time has occurred for 8000 Hz. Although in their field measurements they obtained reverberation times that are longer for middle frequencies and shorter for low and high frequencies, the range of the values are very similar with this study. They have explained short reverberation times for low frequencies with the absorption by the atrium roof glass and shop showcase windows. In addition, they state that glass may act as reflective surfaces for middle and high frequencies. Yet, it should be noted that Chen and Kang (2004) includes the shopping arcades of the shopping centers not the food court areas, which is the main focus of this study. In simulation finding of food court in CEPA, the reverberation times gets shorter by higher frequencies. There is not a very distinct contrast in the maps for the two different frequency ranges (500-1000 Hz). It should be noted that the atrium void and the rear areas are showing worse decay characteristics that are longer than the areas plotted by dark blue color. The main reason for higher reverberation near the atrium void is said to be the glass dome ceiling designed on top of the atrium void. It is known from the literature that domical structures are very affective on the formation of long decay times with un-unified reflections (Egan, 1988).

In addition, the large window glass present at the left façade of the food court could act as a major reflective surface within the space. Yet, the reflected sound waves seem to be absorbed by the atrium void as there is a sudden change in the plot color just after the atrium boundaries in the distribution map. So, it could be said that the void acts as the attenuation chamber for the reflected sounds from the glass window and the glass dome ceiling.

One other study in the literature is Bradley's (1998) on ten different atriums. In this study, the plots of the reverberation times show that the values tend to be highest at mid-frequencies as 500 Hz and 1000 Hz, especially in atria with poor sound absorbing treatment. In their study, absorption of large glass areas have also been mentioned as the primary reason for short reverberation times measured for the low frequencies. In addition, it has also been noted that the reason of short decay times at high frequency sounds is the air absorption relevant for large indoor spaces. However, the simulation values of CEPA show that there is high decay times at low frequencies that are getting shorter by higher frequency ranges.

As Kang (2002) noted in his study on dining spaces, STI is affected by many factors including the shape of the room, seat density and absorber arrangements. As for this study the most important factors that have been taken into consideration are the shape of the room and the materials used in the space. There is a central atrium with a glass dome ceiling above yet the food court area can be characterized to be cubic with two side being fast food kiosks, the left façade of the shopping center food court floor being double-glazed window and the further area beyond the atrium being the restaurants with upholstered armchairs. In this study, only the seats near the atrium void are studied, yet the overall volume is affective for the acoustical characteristics of the considered area. One other important factor is the present reflective materials. There is no intervention regarding absorptive materials.

As specifically indicated in Navarro and Pimentel's (2007) study, food courts should be designed to be a space with low residual noise levels, which can be possible by proper absorptive material treatments. Kang (2002) makes an important comment that the absorber arrangements are crucial to obtain best acoustic environments, where ambient noise levels are low and reflections are prevented for preferred intelligibility scores.

Kang (2002), explains that, 'in dining spaces the seat density is generally less than that in auditoria, the sources and receivers are of the same height, and the 'seat-dip' effect is of less importance in the frequency range of speech' (p. 1318). In this study similarly with, Kang (2002), SPL is considered to be dominated by multiple sound sources including; ambient noise from other people, overall noise in CEPA, music, HVAC, fast food kiosks and overall reflected sounds. All such sounds are also very affective on the signal-to-noise ratio.

It is know from the literature that shape of the enclosure and the volume is very crucial for the acoustical indices that occur in the space (Meissner, 2007, Kang, 2002). In the literature, one of Bradley's (1998) studies, which concentrates on the atriums of different volumes and types within variedly functioned buildings, BNC atrium and SIG atrium are the ones that are comparable to CEPA atrium. The BNC atrium with an octagonal and centralized plan (similar to CEPA) within an office building of seven floors and a cafeteria at the third floor is very similar with a glass ceiling on top of the atrium void. The volume of the atrium void is 28,000m^3 and the A-weighted noise level is measured to be 50.4 dBA. On the other hand, the SIG atrium has a more complicated plan with seven floors and a central atrium with a shape similar to a rectangle. The volume of SIG atrium is 45,000 m^3 and the noise level is measured to be 58.4 dBA. In this study, CEPA Shopping Center has a volume of 145.000 m^3 and the averaged Leq value is 66.7 dBA. Although there are many other factors affecting the noise formation in atriums, in this study it can be proposed that the volume and localization of atrium void as well as its shape is responsible for higher Leq. As seen in Table 5.1, the Leq values of mentioned atriums increase by larger volumes. Yet, there are many other criteria affecting Leq values, so a more detailed comparison and research should be done.

Table 5.1. Leq values compared with different volumes of three varied atriums.

	Volume (m^3)	**Equalized Averaged Noise Level (Leq)**
BNC Atrium, Bell Northern Research Center	28,000	50.4 dBA

SIG Atrium, Palais de Justice, Quebec	45,000	58.4 dBA
CEPA Shopping Center	145,000	66.7 dBA

One other common architectural element is the fountain present both in CEPA and in SIQ atrium. In his measurements, Bradley (1998) noted that the noise coming from the fountain is affective only for the frequencies above 500 Hz. Yet, noise coming from the fountain is crucial for areas where the seating area or food court has a direct relation with it. For SIQ atrium, there is such a relation in which Bradley (1998) explained that it would be advantageous for masking other people's noise for better speech privacy. In CEPA, the fountain is located at down stairs 28 meters below which would be non-affective for the food court area. In addition, in none of the surveys there was a comment regarding the fountain noise, yet its effect on the overall noise formation in CEPA should not be under estimated.

5.2. Relationships between Leq Measurements and Noise Annoyance Ratings

The previously discussed details regarding the Leq measurements and simulation findings of CEPA Shopping Center presents the crucial acoustical incidences and noise formation characteristics within the food court area. Accordingly with these simulation and measurement results, the users' auditory perception and noise annoyance ratings are well related and correlated for both in CEPA and in food court area.

In this study the averaged Leq values are obtained in the food court area of CEPA Shopping Center by one-minute measurements at three different locations at two-hour intervals during one-week period. The results show that, for the weekends the Leq values are found to be 5 dBA higher than the weekdays'. Similarly, in their study on the Sheffield Meadowhall Shopping Center, Chen and Kang (2004) found the result that on the weekdays Leq values are lower than on the weekends.

Regarding the equivalent continuous sound pressure level (Leq) measurements done in this study, the values for the weekdays are increased progressively during the day and got highest in the evening. On the other hand at weekends, the peak value is obtained during the afternoon and the value decreased gradually in the evening hours. The reason for such a variation can be discussed as, due to the usage density of the shopping center and the food court area during different day types and time slots. For instance, a more crowded group of people uses the food court area as the result of their tendency for shopping in the weekends.

Users' time spent preferences are found to be well related with their noise annoyance ratings in food court, as majority of the users (94%) have higher noise annoyance ratings and shorter time spent preferences (1-2 hours) in the food court. The rest of the users are the ones that are less annoyed by noise and tend to stay longer in the food court area. In addition, all other possible factors as; demographic characteristics (gender, age, education) and activities (w/out conversation) held in food court area, that may influence the users' noise annoyance ratings are defined and correlated. There found to be no significant correlation between demographics and noise annoyance ratings. These findings are in accordance with Chen and Kang's (2004) study. Another supportive finding for this assertion is obtained by seeking the annoyance ratings of the sample group, with two basic questions regarding noise annoyance during eating and during conversation in a noisy environment in general. The correlations show that the user group tends to be annoyed at the same rate for the activities of eating and conversation.

An important result is that users can perceive the dBA changes for weekdays and weekends. For this specific case and study, noise measurements showed that there is nearly a 5 dBA change between weekday and weekend Leq values. The annoyance from other people in food court showed that 71.7 percent of the users rated the weekends to be noisy-4 or very noisy-5. On the other hand, 55.8 percent rated the weekdays to be noisy-4 or very noisy-5. There is nearly a 15 percent increase on the noise annoyance ratings for the weekends (see Figure 5.1).

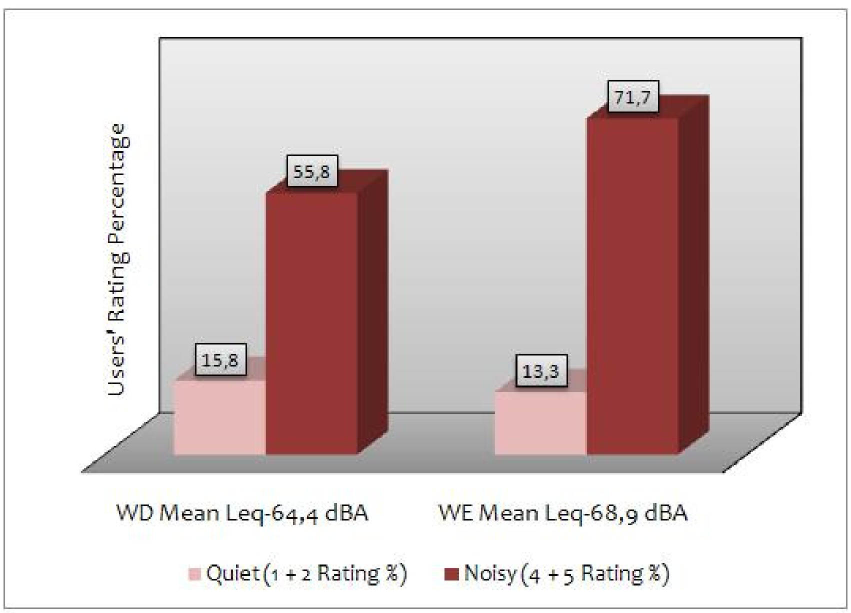


Figure 5.1. Rating percentages for annoyance from other people in food court (quiet and noisy) related with mean Leq values of weekdays and weekends.

The linear regression analysis shows that there found to be no significant correlation between the measured Leq values and the noise annoyance from other people in food court area (p=0.161). Yet, there found to be a significant correlation between the measured Leq values and the annoyance ratings of food court users from the overall noise in CEPA Shopping Center (p=0.052) (see Appendix C, Table C1.11). In Figure 5.2, the linear regression graph is given accordingly and the regression line can be plotted from the given data. It is clearly seen that the annoyance ratings are getting increased by higher Leq values.

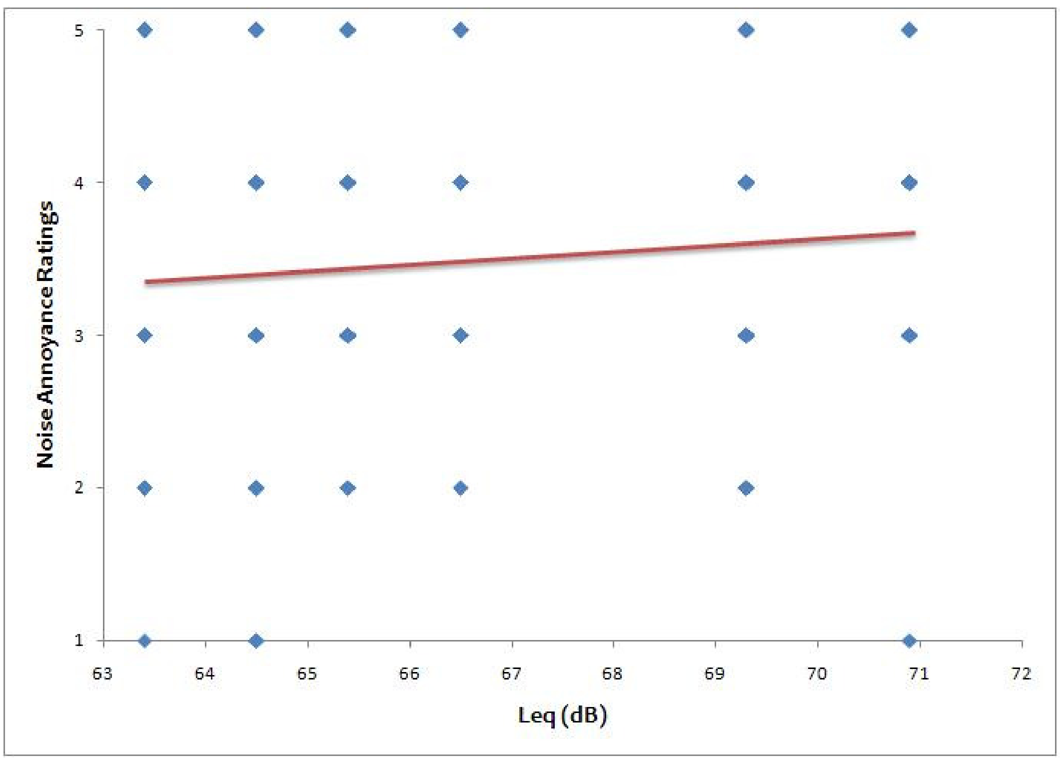


Figure 5.2. Linear regression graph for annoyance of food court users from the overall noise in CEPA and the measured Leq values. ◆ object indicates the users' noise annoyance ratings for the varied Leq situations.

Measured Leq values at different time slots and day types were tried to be related to the annoyance from other people in food court during these predefined times. In Figure 5.3, the percentages of the noise annoyance ratings of the users show that during noon both for weekdays and weekends there is a considerable increase.

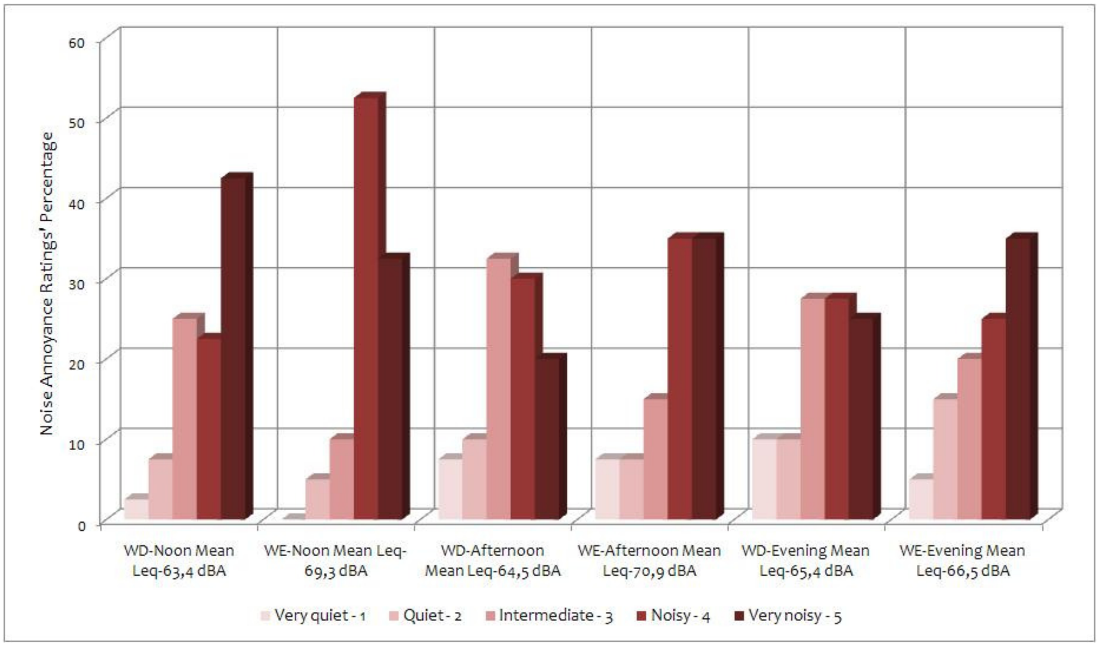


Figure 5.3. Rating percentages for annoyance from other people in food court (1 to 5) related with different day types and times of the day.

6. CONCLUSION

This case study held in food court area of CEPA Shopping Center analysis the relation between the objective and subjective results obtained by simulations, measurements, and questionnaires. It is concluded that, in such enclosed public spaces like shopping centers, equivalent continuous sound pressure level are found to be higher at weekends probably due to increased crowding. The simulation results showed that atriums and glass dome ceilings are the main architectural features that lead to the negative acoustical incidences as long early decay times and reverberation times and poor speech transmission index (0.37).

Although, there are many studies regarding noise annoyance and objective acoustical parameters in public spaces, there are few that highly concentrate on the relation of subjective evaluation and objective conditions and characteristics of an enclosed space. In this study, such a relation is tried to be put forth. The perceived noisiness and noise annoyance ratings obtained by the questionnaires, are well related with all these measured and simulated findings. The linear regression analysis presents the correlations between the measured Leq values and the annoyance of food court users from the overall noise in CEPA. Time spent preference in food court is found to be significantly decreased due to high noise annoyance of the users. All the quantitative and qualitative outcomes derived by this study, presents corresponding results.

In this study, by correlating the Leq values and noise annoyance ratings during different time slots, a significant literature supporting finding is obtained. As it is noted in the literature (Egan, 1988) the apparent loudness is clearly noticeable when a change of 6dB on the sound pressure level occurs. Similarly, the users in food court in CEPA could only detect the Leq difference of 6.4 dBA for the afternoons of weekdays and weekends. Yet, the Leq difference of 5.9 dBA for the weekdays and the weekends noon or the Leq difference of 1.1 dBA for weekdays and weekends evening are not reflected on the users annoyance ratings.

One weakness for relating subjective and objective evaluation is the enclosed space that the study takes place. First of all there are many uncontrollable factors in such spaces as the measurements and surveys would not be able to done at the same time. There would be needed a research group who would accomplish the measurements at the same time with the questionnaires so that the time periods would be more concrete and a series of data could be gathered for more detailed comparative graphs.

Further studies could also include indoor soundscape approach, which can be done in anechoic rooms with recorded noise samples and intelligibility or articulation tests. It should be noted that speech intelligibility tests are more reliable assessment tools than surveys. There is still a gap in the literature for defining acoustical comfort ratings and noise annoyance ratings. The strict determination could still not be done between these two terminologies.

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APPENDIX A

Appendix A1: AutoCAD Drawings

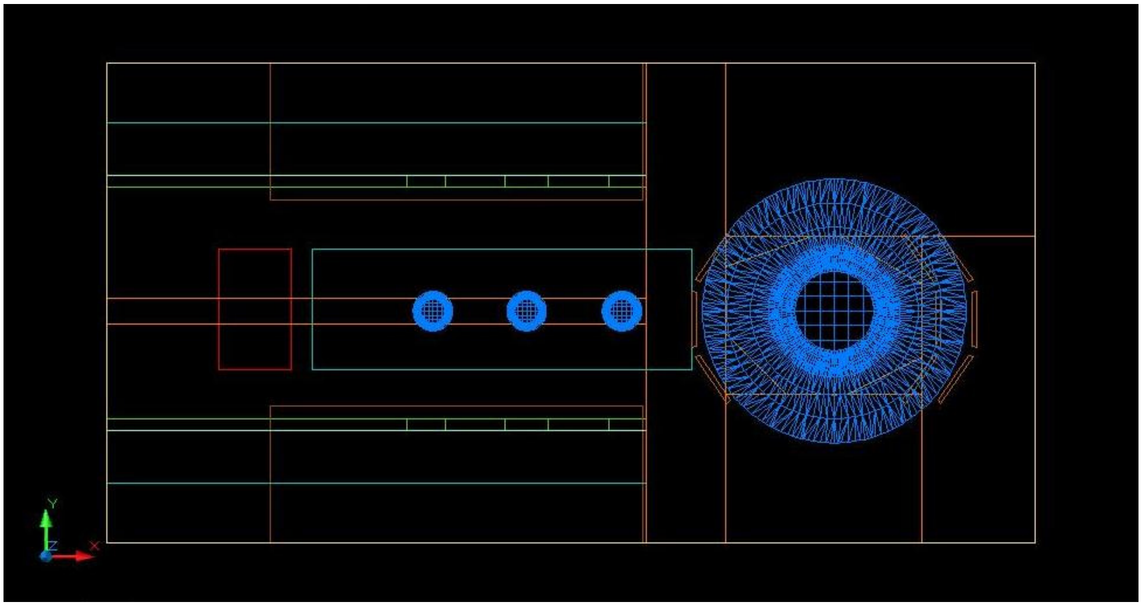

Figure A1.1. Plan of the CEPA Shopping Center as modeled in AutoCAD .

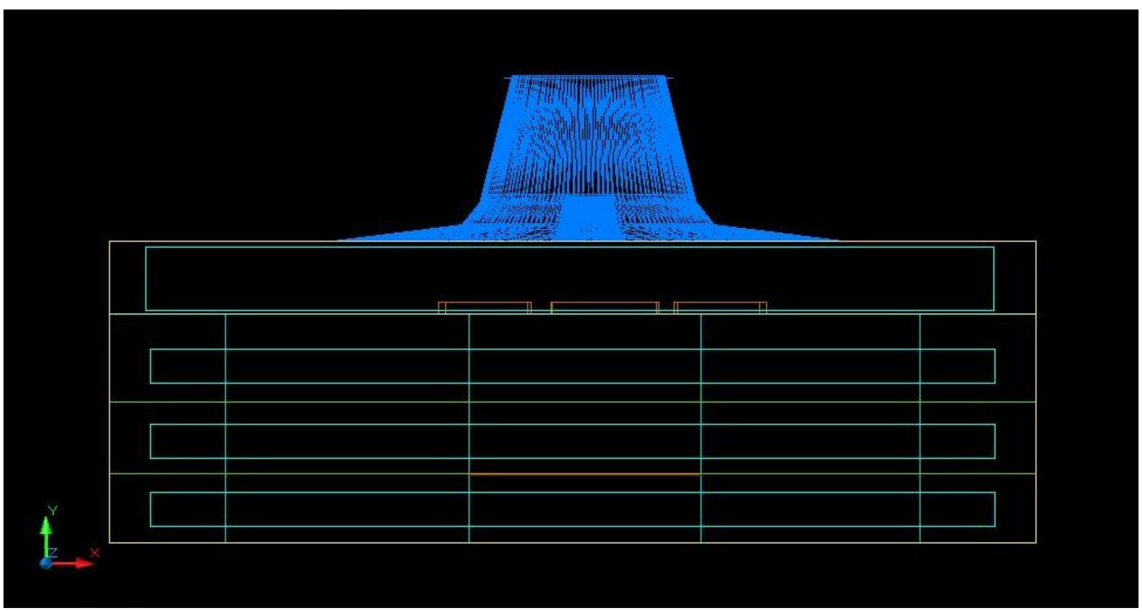

Figure A1.2. Side view of the CEPA Shopping Center as modeled in AutoCAD .

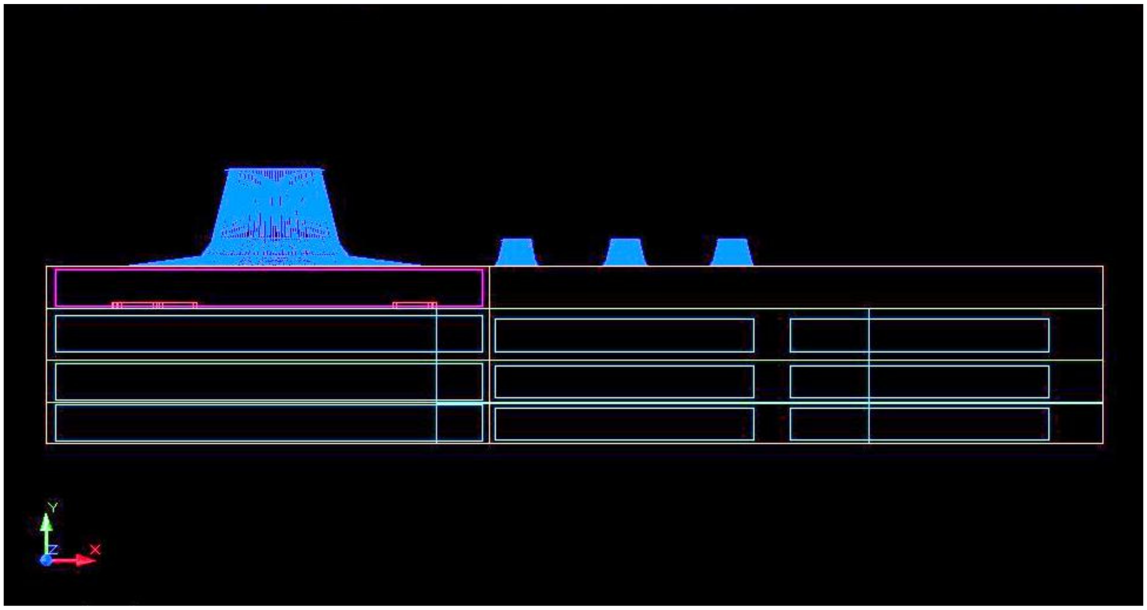

Figure A1.3. Front view of the CEPA Shopping Center as modeled in AutoCAD .

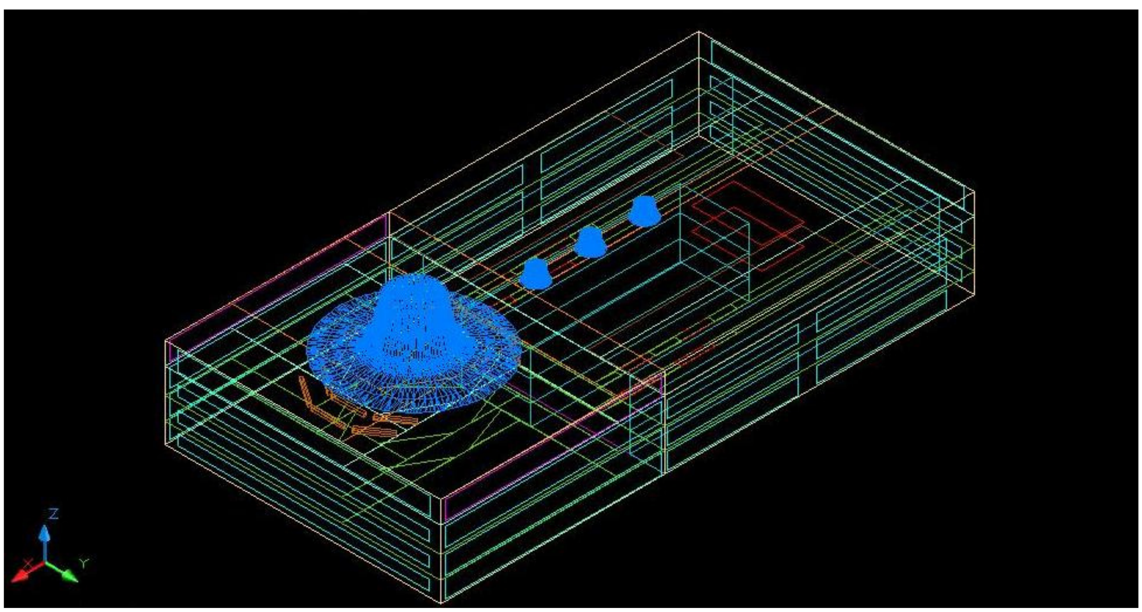

Figure A1.4. Axonometric view of the CEPA Shopping Center as modeled in AutoCAD .

APPENDIX B

Appendix B1: Distributions Maps of Computer Simulation

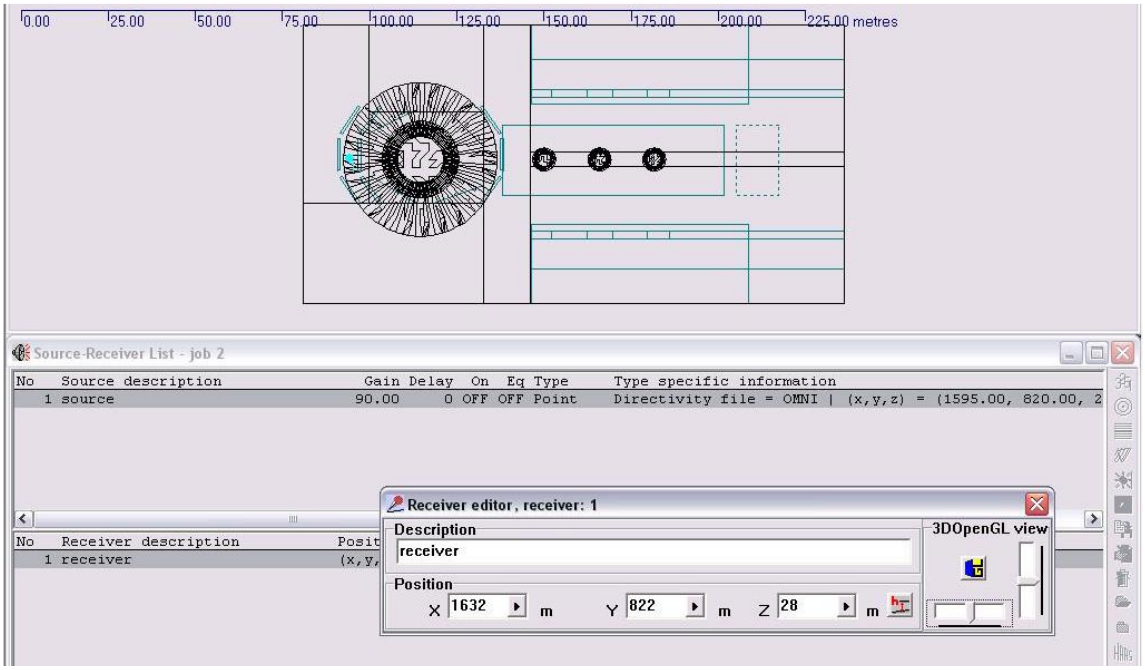

Figure B1.1. Receiver location information of the computer simulation.

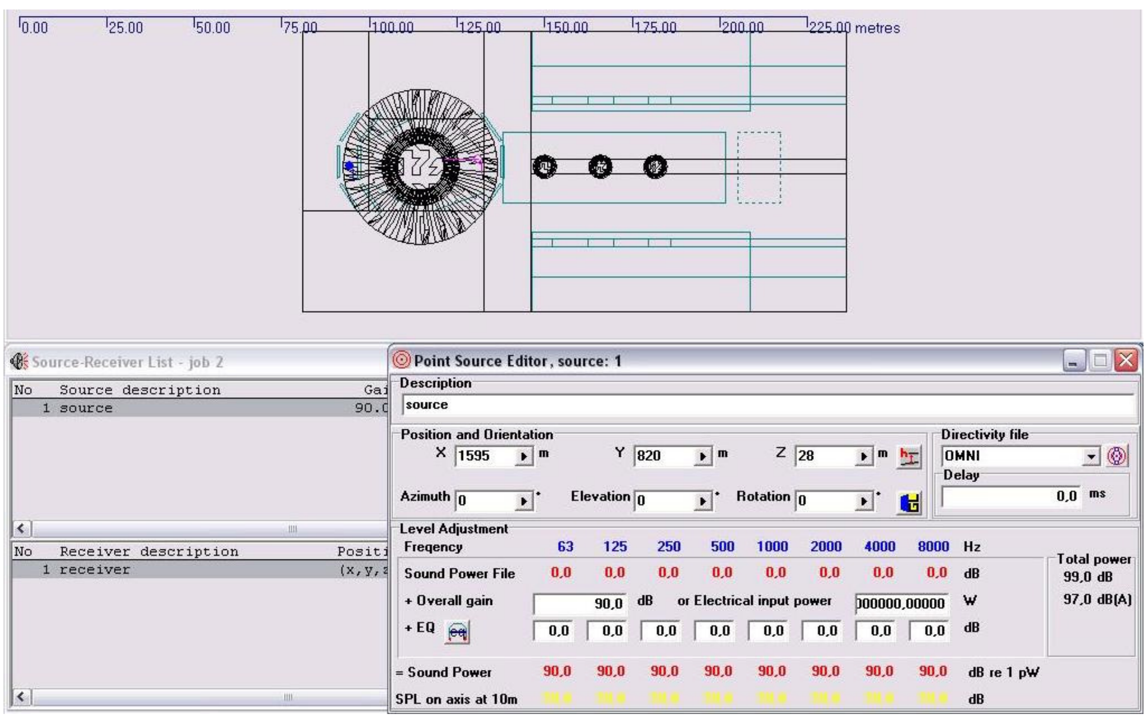

Figure B1.2. Source location information of the computer simulation.

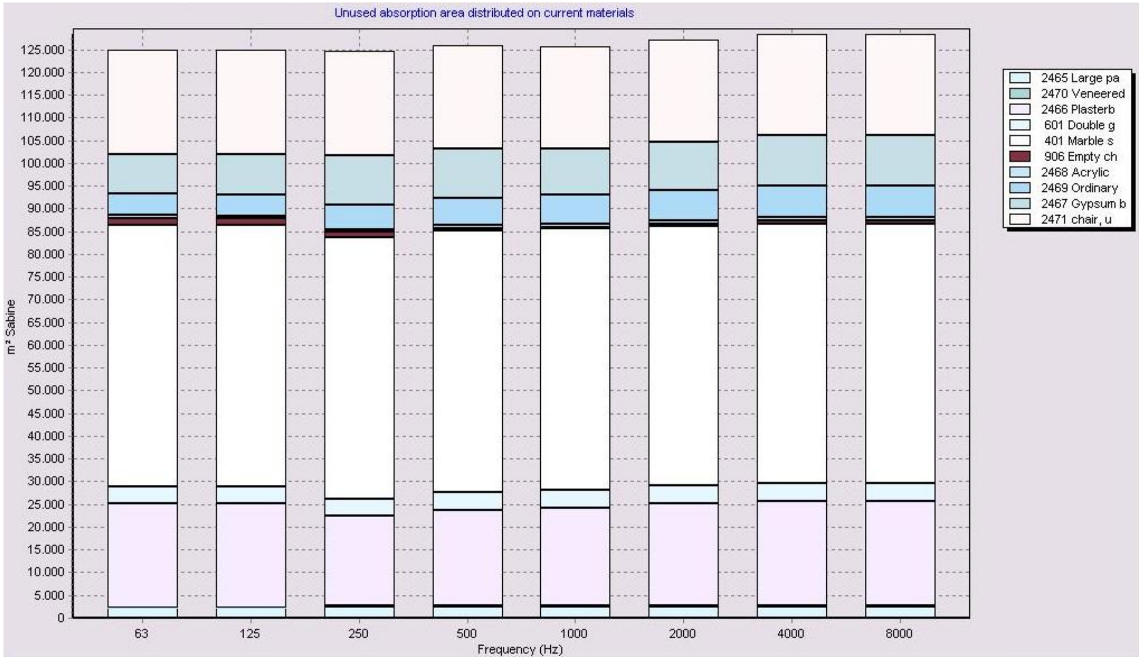

Figure B1.3. Bar chart showing the unused absorption area on current materials for the computer simulation.

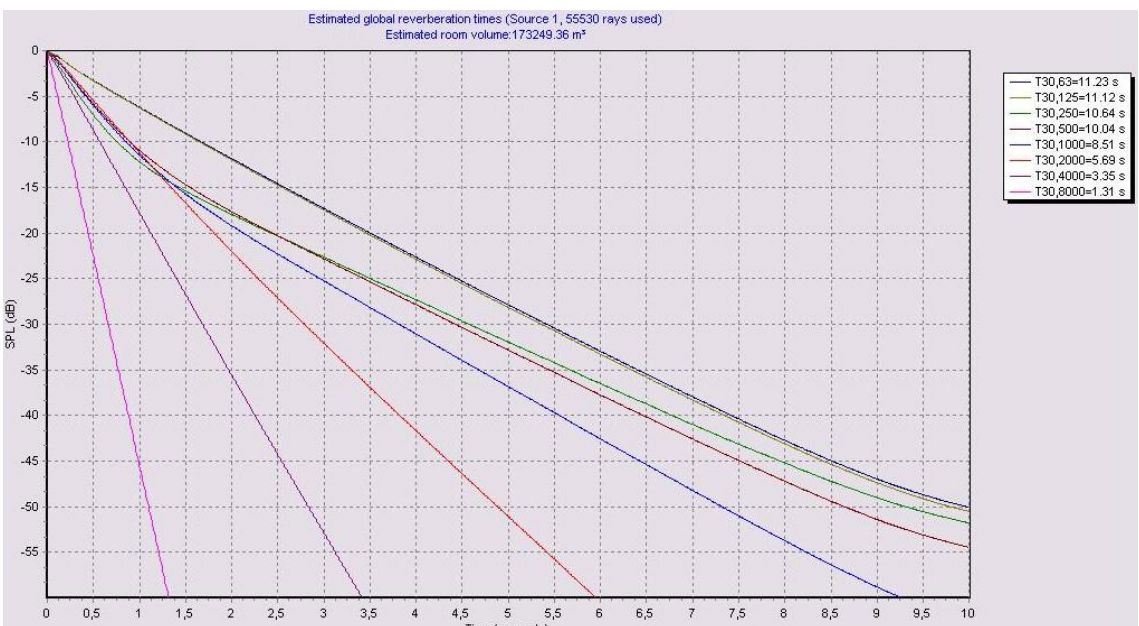

Figure B1.4. Graph showing the estimated global reverberation times for frequencies between 63 Hz – 8000 Hz.

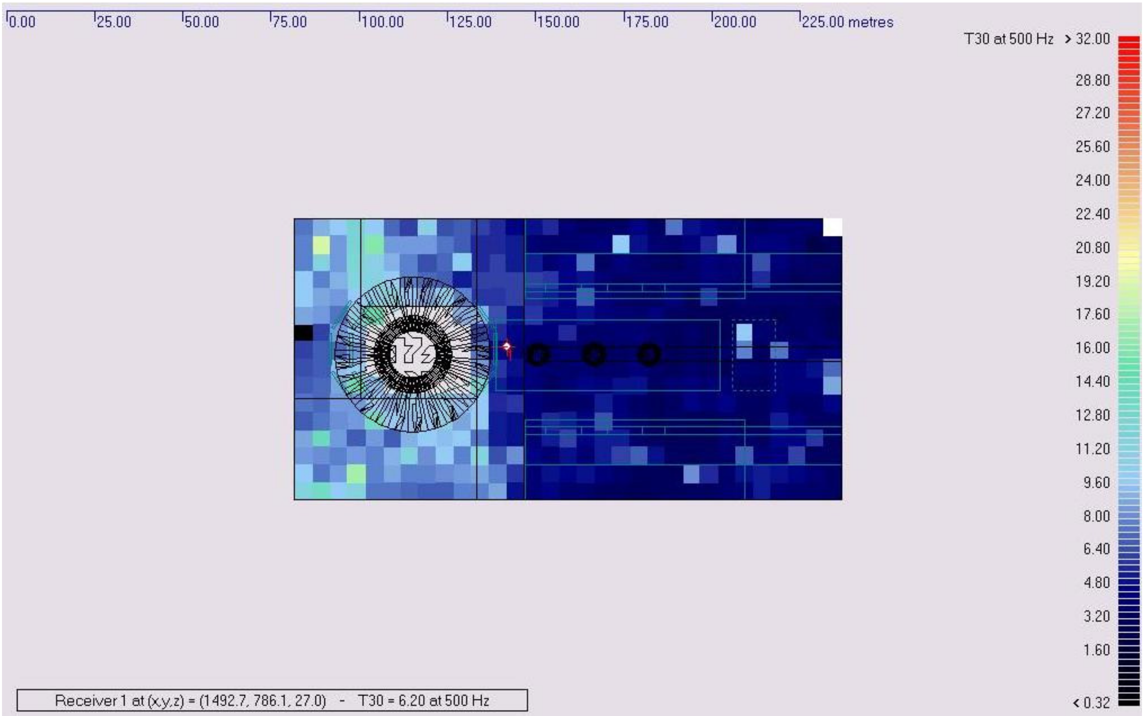

Figure B1.5. T30 distribution map for 500 Hz.

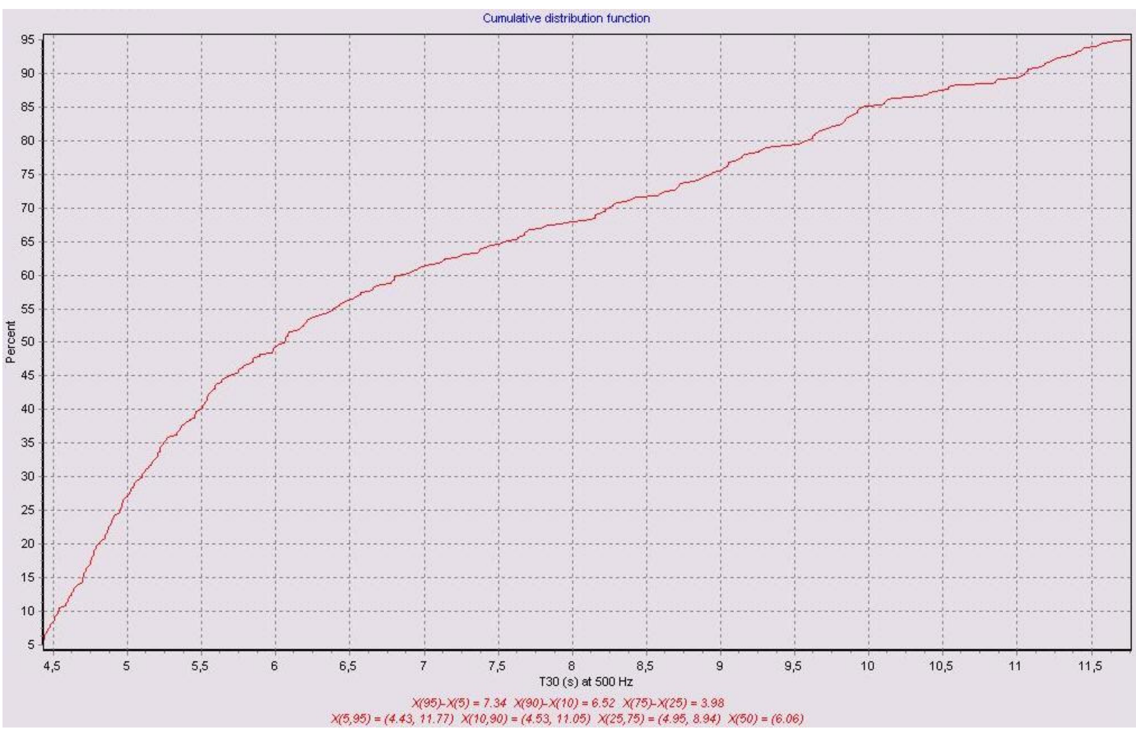

Figure B1.6. Cumulative distribution function graph of T30 at 500 Hz.

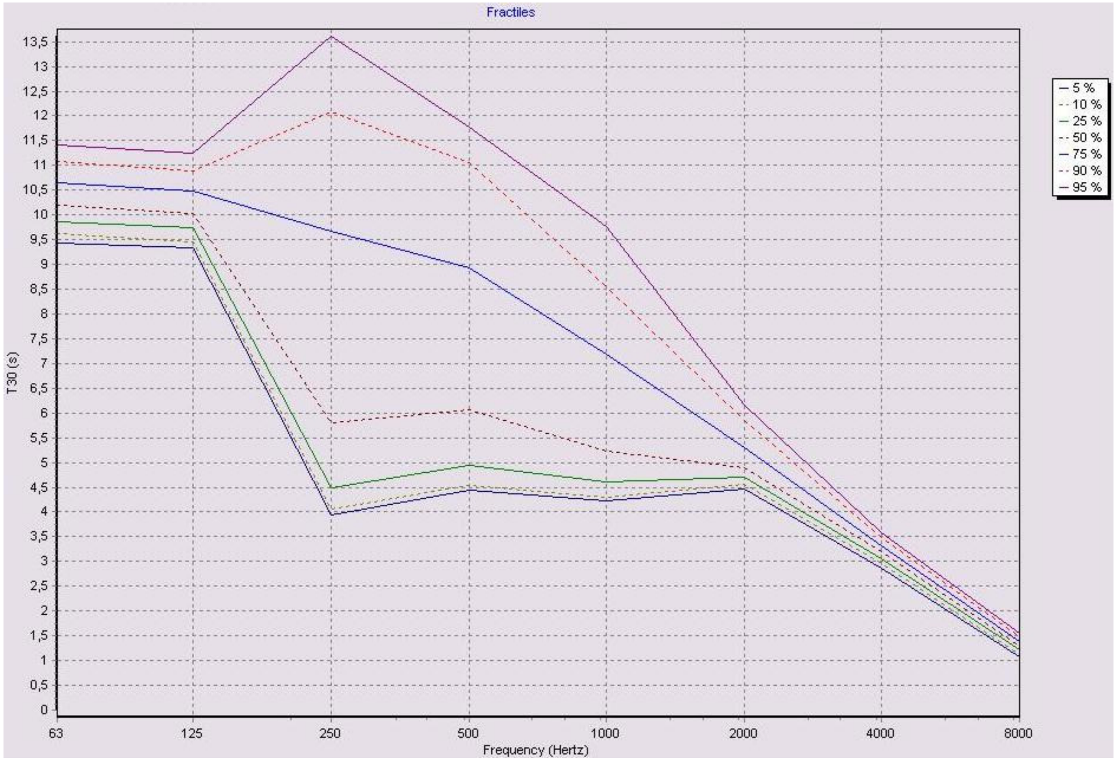

Figure B1.7. T30 percentile fractiles for frequencies between 63-8000 Hz .

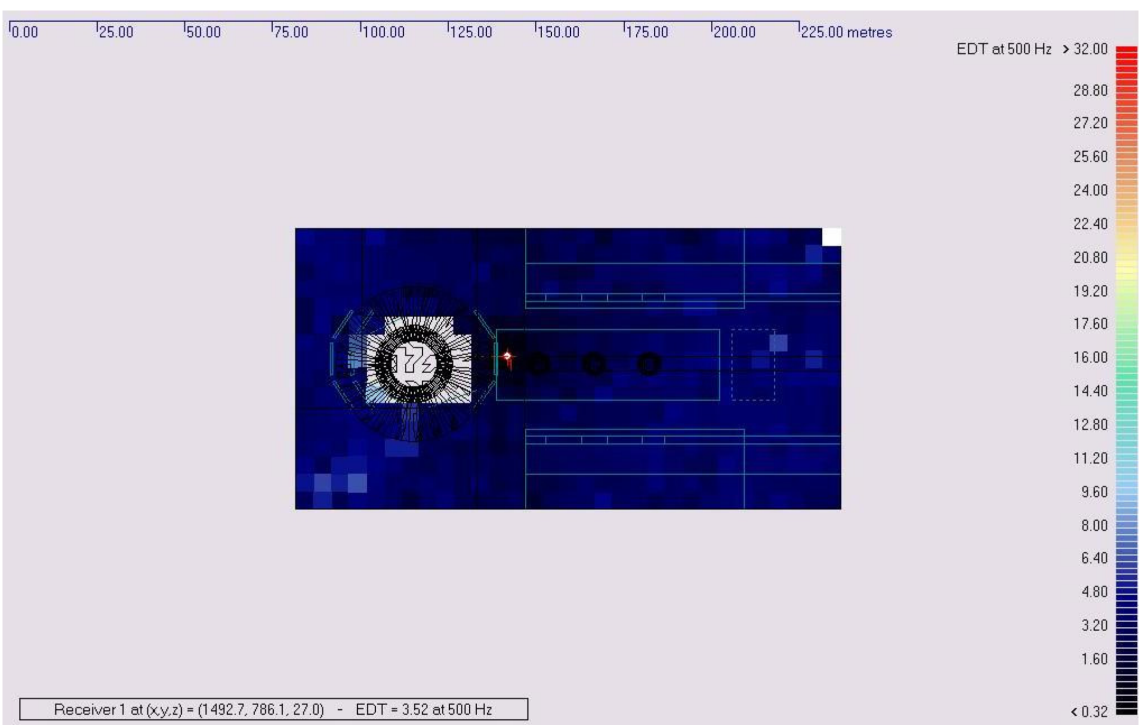

Figure B1.8. EDT distribution map for 500 Hz.

Figure B1.9. Cumulative distribution function graph of EDT at 500 Hz.

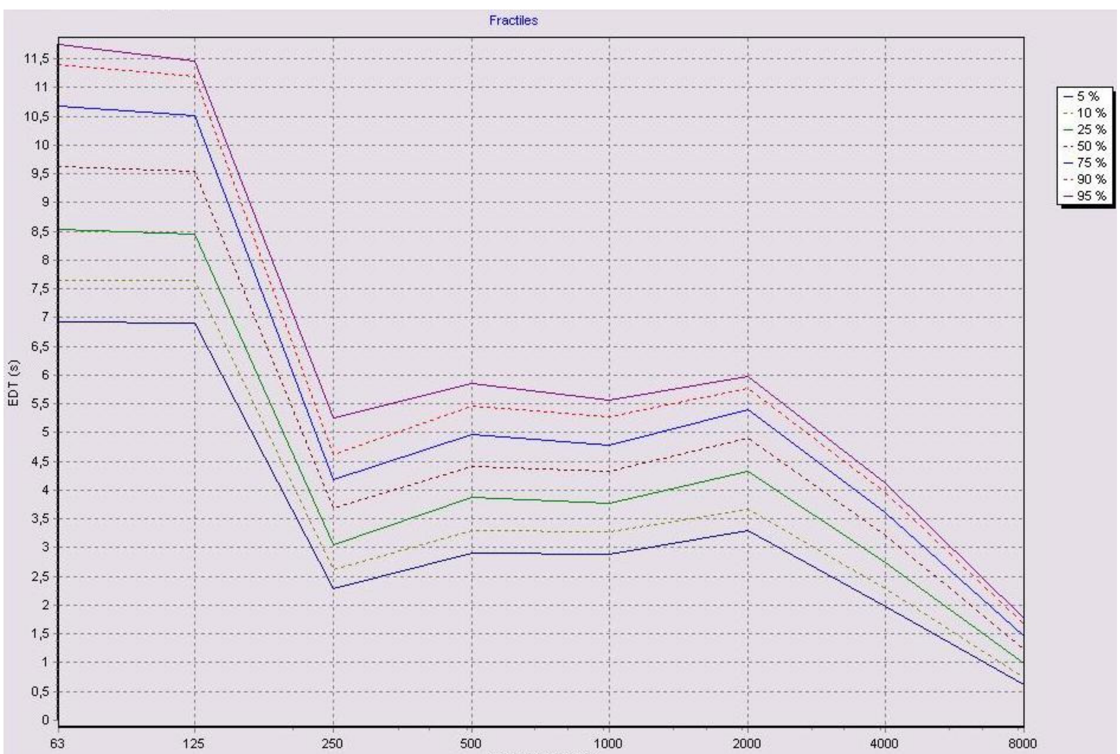

Figure B1.10. EDT percentile fractiles for frequencies between 63-8000 Hz .

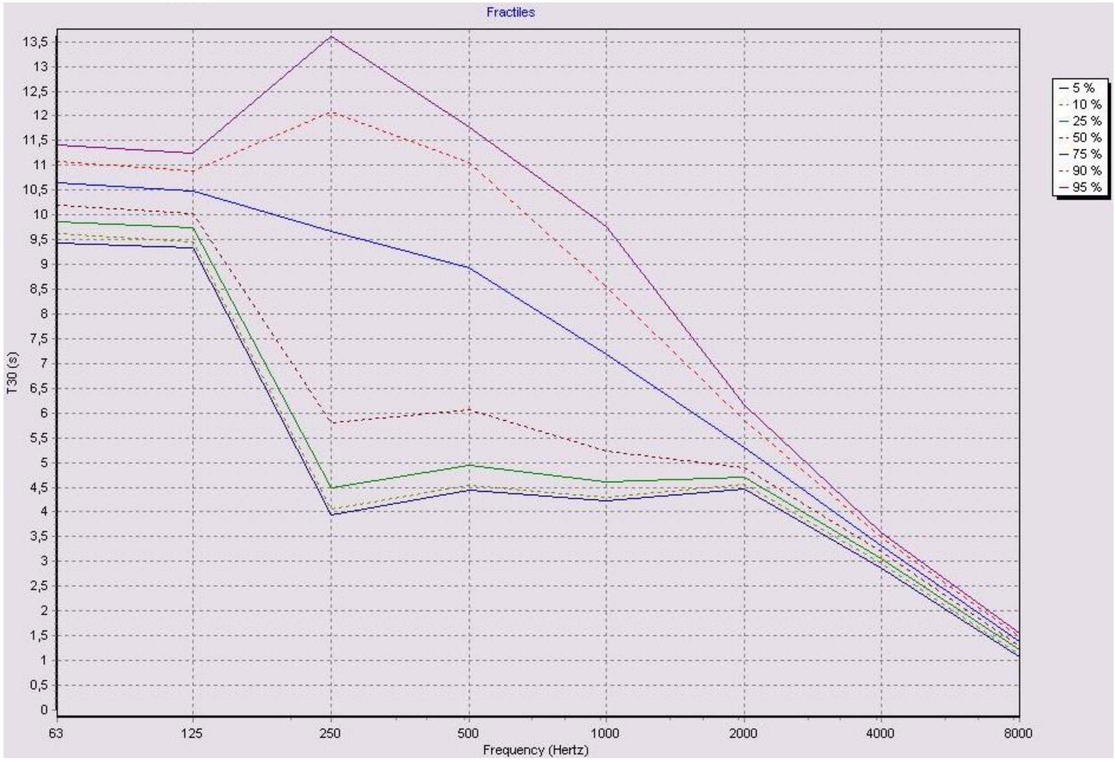

Figure B1.11. T30 percentile fractiles for frequencies between 63-8000 Hz .

Figure B1.12. Cumulative distribution function graph of STI.

APPENDIX C

Appendix C1: Questionnaires and Correlations

Table C1.1. a) Cross tabulation, b) Chi-square tests, and c) Symmetric measures of Kendall's Tau-c coefficients test results for the correlation between noise annoyance during eating and noise annoyance during conversation.

a) **Cross tabulation**

			Noise annoyance during conversation					Total
			Less	2	3	4	High	Less
Noise annoyance during eating	Less	Count	3	4	5	2	3	17
		% within Noise annoyance during eating	17,6%	23,5%	29,4%	11,8%	17,6%	100,0%
	2	Count	0	6	4	7	4	21
		% within Noise annoyance during eating	,0%	28,6%	19,0%	33,3%	19,0%	100,0%
	3	Count	2	1	13	15	17	48
		% within Noise annoyance during eating	4,2%	2,1%	27,1%	31,3%	35,4%	100,0%
	4	Count	1	1	1	26	42	71
		% within Noise annoyance during eating	1,4%	1,4%	1,4%	36,6%	59,2%	100,0%
	High	Count	0	0	0	4	79	83
		% within Noise annoyance during eating	,0%	,0%	,0%	4,8%	95,2%	100,0%
Total		Count	6	12	23	54	145	240
		% within Noise annoyance during eating	2,5%	5,0%	9,6%	22,5%	60,4%	100,0%

a) Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	152,168(a)	16	,000
Likelihood Ratio	142,555	16	,000
Linear-by-Linear Association	93,260	1	,000
N of Valid Cases	240		

a 15 cells (60,0%) have expected count less than 5. The minimum expected count is ,43.

b) Symmetric Measures

		Value	Asymp. Std. Error(a)	Approx. T(b)	Approx. Sig.
Ordinal by Ordinal	**Kendall's tau-c**	,459	,037	12,287	,000
N of Valid Cases		240			

a Not assuming the null hypothesis.
b Using the asymptotic standard error assuming the null hypothesis.

Table C1.2. a) Cross tabulation, b) Chi-square tests, and c) Symmetric measures of Kendall's Tau-c coefficients test results for the correlation between noise annoyance during conversation and noise annoyance from other people in food court.

a) Crosstabulation

			Noise annoyance from other people in food court					Total
			Less	2	3	4	Very	Less
Noise annoyance during conversation	Less	Count	3	2	1	0	0	6
		% within Noise annoyance during conv.	50,0%	33,3%	16,7%	,0%	,0%	100,0%
	2	Count	1	7	3	1	0	12
		% within Noise annoyance during conv.	8,3%	58,3%	25,0%	8,3%	,0%	100,0%
	3	Count	0	2	11	8	2	23
		% within Noise annoyance during conv.	,0%	8,7%	47,8%	34,8%	8,7%	100,0%
	4	Count	3	4	13	26	8	54
		% within Noise annoyance during conv.	5,6%	7,4%	24,1%	48,1%	14,8%	100,0%
	Very	Count	6	7	24	42	66	145
		% within Noise annoyance during conversation	4,1%	4,8%	16,6%	29,0%	45,5%	100,0%
Total		Count	13	22	52	77	76	240
		% within Noise annoyance during conversation	5,4%	9,2%	21,7%	32,1%	31,7%	100,0%

b) Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	103,845(a)	16	,000
Likelihood Ratio	80,551	16	,000
Linear-by-Linear Association	47,928	1	,000
N of Valid Cases	240		

a 15 cells (60,0%) have expected count less than 5. The minimum expected count is ,33.

c) Symmetric Measures

		Value	Asymp. Std. Error(a)	Approx. T(b)	Approx. Sig.
Ordinal by Ordinal	**Kendall's tau-c**	,303	,044	6,942	,000
N of Valid Cases		240			

a Not assuming the null hypothesis.
b Using the asymptotic standard error assuming the null hypothesis.

Table C1.3. a) Cross tabulation b) Chi-Square tests of Chi-Square Test results for the correlation between the most dominantly perceived sound and the most annoying sound.

a) Crosstabulation

			The most annoying sound				Total
			Speech noise	**Hum of voices**	**Crackle of tables, trays**	**Nothing**	**Speech noise**
The most dominantly perceived sound	**Speech noise**	Count	55	43	8	12	118
		% within The most annoying sound	67,9%	36,8%	42,1%	52,2%	49,2%
	Hum of voices	Count	7	48	2	3	60
		% within The most annoying sound	8,6%	41,0%	10,5%	13,0%	25,0%
	Crackle of tables, trays	Count	3	4	7	0	14
		% within The most annoying sound	3,7%	3,4%	36,8%	,0%	5,8%
	Children shooting	Count	8	13	1	2	24
		% within The	9,9%	11,1%	5,3%	8,7%	10,0%

	most annoying sound					
Music	Count	8	9	1	6	24
	% within The most annoying sound	9,9%	7,7%	5,3%	26,1%	10,0%
Total	Count	81	117	19	23	240
	% within Most annoying sound	100,0%	100,0%	100,0%	100,0%	100,0%

b) Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	75,355(a)	12	,000
Likelihood Ratio	59,546	12	,000
Linear-by-Linear Association	3,883	1	,049
N of Valid Cases	240		

a 8 cells (40,0%) have expected count less than 5. The minimum expected count is 1,11.

Table C1.4. a) Descriptives b) Ranks and c) Statistics of Mann-Whitney U Test results for the correlation between noise annoyance from other people in food court or annoyance from overall noise in CEPA at weekdays or weekends.

a) Descriptives

	Day types			Statistic	Std. Error
Annoyance from overall noise in CEPA	Weekdays	Mean		3,38	,089
		95% Confidence Interval for Mean	Lower Bound	3,21	
			Upper Bound	3,56	
		5% Trimmed Mean		3,41	
		Median		3,00	
		Variance		,944	
		Std. Deviation		,972	
		Minimum		1	
		Maximum		5	
		Range		4	
		Interquartile Range		1	
		Skewness		-,167	,221
		Kurtosis		-,144	,438
	Weekends	Mean		3,68	,072
		95% Confidence Interval for Mean	Lower Bound	3,53	
			Upper Bound	3,82	
		5% Trimmed Mean		3,70	

				Statistic	Std. Error
		Median		4,00	
		Variance		,625	
		Std. Deviation		,790	
		Minimum		1	
		Maximum		5	
		Range		4	
		Interquartile Range		1	
		Skewness		-,284	,221
		Kurtosis		,304	,438
Noise annoyance from other people in food court	Weekdays	Mean		3,63	,109
		95% Confidence Interval for Mean	Lower Bound	3,41	
			Upper Bound	3,84	
		5% Trimmed Mean		3,69	
		Median		4,00	
		Variance		1,413	
		Std. Deviation		1,189	
		Minimum		1	
		Maximum		5	
		Range		4	
		Interquartile Range		2	
		Skewness		-,547	,221
		Kurtosis		-,476	,438
	Weekends	Mean		3,88	,101
		95% Confidence Interval for Mean	Lower Bound	3,68	
			Upper Bound	4,08	
		5% Trimmed Mean		3,97	
		Median		4,00	
		Variance		1,230	
		Std. Deviation		1,109	
		Minimum		1	
		Maximum		5	
		Range		4	
		Interquartile Range		2	
		Skewness		-,931	,221
		Kurtosis		,187	,438

b) Ranks

	Day type	N	Mean Rank	Sum of Ranks
Annoyance from overall noise in CEPA	Weekdays	120	109,91	13189,00
	Weekends	120	131,09	15731,00
	Total	240		

Noise annoyance from other people in food court	Weekdays	120	112,80	13536,00
	Weekends	120	128,20	15384,00
	Total	240		

c) Test Statistics(a)

	Annoyance from overall noise in CEPA	Noise annoyance from other people in food court
Mann-Whitney U	5929,000	6276,000
Wilcoxon W	13189,000	13536,000
Z	-2,513	-1,787
Asymp. Sig. (2-tailed)	,012	,074

a Grouping Variable: grup1

Table C1.5. a) Descriptives, b) Ranks, and c) Test statistics of Kruskal-Wallis one-way ANOVA test results for the time spent in food court and noise annoyance from other people in food court.

a) Descriptives

	Time spent in food court			Statistic	Std. Error
Noise annoyance from other people in food court	1-2hours	Mean		3,75	,076
		95% Confidence Interval for Mean	Lower Bound	3,60	
			Upper Bound	3,90	
		5% Trimmed Mean		3,83	
		Median		4,00	
		Variance		1,315	
		Std. Deviation		1,147	
		Minimum		1	
		Maximum		5	
		Range		4	
		Interquartile Range		2	
		Skewness		-,709	,162
		Kurtosis		-,235	,323
	3-4hours	Mean		4,50	,167
		95% Confidence Interval for Mean	Lower Bound	4,12	
			Upper Bound	4,88	
		5% Trimmed Mean		4,50	

		Median		4,50	
		Variance		,278	
		Std. Deviation		,527	
		Minimum		4	
		Maximum		5	
		Range		1	
		Interquartile Range		1	
		Skewness		,000	,687
		Kurtosis		-2,571	1,334
	More than 4 hours	Mean		2,60	,678
		95% Confidence Interval for Mean	Lower Bound	,72	
			Upper Bound	4,48	
		5% Trimmed Mean		2,56	
		Median		2,00	
		Variance		2,300	
		Std. Deviation		1,517	
		Minimum		1	
		Maximum		5	
		Range		4	
		Interquartile Range		3	
		Skewness		1,118	,913
		Kurtosis		1,456	2,000

b) Ranks

	Time spent in food court	N	Mean Rank
Noise annoyance from other people in food court	1-2hours	225	119,81
	3-4hours	10	164,25
	More than 4 hours	5	64,00
	Total	240	

c) Test Statistics(a,b)

	Yemek katinda diger insanlarin sesinden ne kadar rahatsiz oluyorsunuz?
Chi-Square	7,904
df	2
Asymp. Sig.	,019

a Kruskal Wallis Test
b Grouping Variable: Food court da gecirilen sure

Appendix C2: Auditory Perception and Noise Annoyance Survey

Acoustic Comfort and Noise Management Survey

This survey is prepared for Building Sciences Master Program in the Department of Interior Architecture and Environmental Design at Bilkent University.

A)

1- Gender:

☐ F ☐ M

2- Age:

☐ 20-35 ☐ 36-50 ☐ 51-65

3- Education:

☐ Primary School ☐ High School ☐ University ☐ Master's/PhD

B)

4- How frequent do you come to CEPA?

☐ More than 2 a week ☐ 1 or 2 a week ☐ 1 or 2 a month

5- How long do you stay in CEPA?

☐ 1-2 hours ☐ 3-4 hours ☐ More than 4 hours

6- How is the noise level in CEPA?

Very Quite — Very Noisy

1	2	3	4	5

7- How long do you stay in the food court area?

☐ 1-2 hours ☐ 3-4 hours ☐ More than 4 hours

8- Which activities do you do in the food court area?

- Eating
- Talking
- Tea/Coffee/Smoking
- Reading book/news
- Using computer
- School/Business work

C)

9- How much do you get effected from different types of sounds during your stay in the food court?

Less — Very

	1	2	3	4	5
Music from downstair shops					
Activities in CEPA					
Overall noise in CEPA					
Noise from other people					

10- How much do you get affected by eating in a noisy environment?

Less — Very

1	2	3	4	5

11- How much do you get affected by talking in a noisy environment?

Less — Very

1	2	3	4	5

12- How much do you get affected from noise of other people in the food court?

Less — Very

1	2	3	4	5

13- What are the annoying sounds you hear while you fill this survey?

……………………………………………………………………

14- What is the most annoying sound you hear while you fill this survey?

…………………………………………………………..........

Thank you for attending this survey!

Akustik Konfor ve Gürültü Denetimi Anketi

Bu anket İç Mimarlık ve Çevre Tasarımı bölümü, Çevre Analizi II dersinin araştırması için hazırlanmıştır. Herhangi başka bir amaçla kullanılmayacaktır.

A)

1- Cinsiyetiniz:

□ K □ E

2- Yaşınız:

□ 20-35 □ 36-50 □ 51-65

3- Eğitim durumunuz:

□ İlkokul □ Lise □ Üniversite □ Yüksek Lisans

B)

4- CEPA'ya geliş sıklığınız nedir?

□ Haftada 2'den fazla □ Haftada 1-2 □ Ayda 1-2

5- CEPA'da geçirdiğiniz süre ne kadar?

□ 1-2 Saat □ 3-4 Saat □ 4 Saatten Fazla

6- CEPA'da ki gürültü seviyesini değerlendiriniz.

Çok Sakin				Çok Gürültülü
1	2	3	4	5

7- Yemek katında ne kadar zaman geçiriyorsunuz?

□ 1-2 Saat □ 3-4 Saat □ 4 Saatten Fazla

8- Hangi aktiviteleri bu mekanda gerçekleştiriyorsunuz?

- Yemek
- Sohbet
- Kahve/Çay/Sigara
- Kitap/Gazete Okumak
- Bilgisayar kullanmak
- İş/Ders ile ilgilenmek

C)

9- Yemek katında bulunduğunuz süre boyunca ne tip seslerden, ne kadar etkileniyorsunuz?

	Az				Çok
	1	2	3	4	5
Mağazalardan gelen müzik sesi					
CEPA'daki aktivitelerden gelen ses					
CEPA'daki genel gürültü					
Diğer insanlardan gelen ses					

10- Gürültülü bir mekanda yemek yemeniz sizi ne kadar etkiler?

Az				Çok
1	2	3	4	5

11- Gürültülü bir mekanda sohbet etmek sizi ne kadar etkiler?

Az				Çok
1	2	3	4	5

12- Yemek katında diğer insanların sesinden ne kadar rahatsız oluyorsunuz?

Az				Çok
1	2	3	4	5

13- Bu anketi yaparken rahatsız olduğunuz sesler nelerdir?

……………………………………………………………………

14- Bu anketi yaparken algıladığınız en baskın ses nedir?

………………………………………………………….........

Bu ankete katıldığınız ve zaman ayırdığınız için teşekkürler!