Müge İyidir. M.A. student of ITU **Graduate School of Arts and Social Sciences,** student ID 409141115, will defend the thesis draft "**PERCEIVED SOUND PRESSURE LEVEL DIFFERENCES IN VARIOUS MOVIE THEATERS IN İSTANBUL**", which she will prepare after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

Thesis Advisor:	**Assist. Prof. Dr. Taylan Özdemir** Istanbul Technical University	**……...……**
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Eşime ve çocuklarıma,

FOREWORD

I've been interested to survey why there are so many loudness wars in broadcast since I work as a sound engineer in post production. The customers work on commercials always demand highest possible loudness levels. However, not only just commercials have sound level differences between each other but the broadcasts in TV series and movies are not the same sound levels. I questioned if the sound levels is same between different movie theaters. Thus, I picked two material to measure that are Phonic PAA2 Meter which has a built in omni-directional condenser calibrated measurement microphone and Decibel X Pro application for iphone (with built-in microphone) to analyze this question.

Firstly, I want to thank to audio engineer Gök Gürhan Berkel for his positive input to my research and also I'd like to thank Assist. Prof. Dr. Taylan Özdemir for his support during the research of my project. It was a great experience to analyze two different movies on four different movie theaters which have individual sound systems and acoustics in İstanbul.

June 2019 Müge İYİDİR

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ABBREVIATIONS

SPL	**:** Sound Pressure Level
PSPL	**:** Peak Sound Pressure level
ITU	**:** The International Telecommunication Union's
EBU	**:** The European Broadcasting Union
dB	**:** Decibels
Hz	**:** Hertz
kHz	**:** Kilohertz
PAA2	**:** PHONIC Personal Audio Assistant
TWA	**:** Time-Weighted Average
RTA	**:** Real time analyzer
Dolby SR	**:** Dolby Spectral Recording
SMPTE	**:** Society of Motion Picture and Television Engineers
LFE	**:** Low Frequency Effect
LS	**:** Left Surround
RS	**:** Right Surround
C	**:** Center
L	**:** Left
R	**:** Right
DTS	**:** Digital Theater Systems
LUFS	**:** Loudness Units Full Scale
CALM	**:** Commercial Advertisement Loudness Mitigation

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PERCEIVED SOUND PRESSURE LEVEL DIFFERENCES IN VARIOUS MOVIE THEATERS IN İSTANBUL

SUMMARY

When you go to a movie theater as an audience, did you ever thought the sound levels were too high? If yes, what would be causing it? Was it the original mix made for this film or the mix of the film transfers differently on every different cinema system.

This project examined and compared perceived sound pressure level differences of different movies (The Avengers: Infinity War and The Cleaning Lady) which were screened on various movie theaters in İstanbul.

Do we see a distinct number of sound pressure level differences throughout the frequency spectrum between each movie theater based on these two movies? Can we prove these Sound Pressure Level (SPL) differences by comparing each different movie theater's analysis? These are the main aspects and concerns of this project.

I approached the subject first as an audio engineer by analyzing collected data. Also, as a member of the audience, I compared the results with my personal inference. To do this, I measured and compared the SPL levels in two different movie genres and four different movie theaters in İstanbul. To make this comparison, I used two different devices for SPL meauserements: One of them was a professional portable audio analyzer (Phonic PAA2) with a built-in measurement microphone and the other was a professional audio measurement application (Decibel x Pro) running on a smartphone (iPhone 6S). Both devices were set up with the same specific angle and position on all of the measurements made and the results are compared afterwards.

The outcome of this project is to prove there are comparable SPL differences of four different movie theaters which have variant sound technologies, formats and acoustics.

As a result of the analysis I made, all of these four movie theaters showed conceivable differences in perceived sound pressure levels, based on the characteristics of each individual movie theater. It also showed that different genres of movies (action and thriller) may affect the dynamics of percieved SPLs and it proved how much it can differentiate between various cinema technologies used by different movie theaters.

İSTANBUL'DA ÇEŞİTLİ SİNEMA SALONLARINDAKİ SES SEVİYESİ FARKLARI

ÖZET

Bir sinemaya seyirci olarak gittiğinizde içerdeki ses seviyesinin fazla yüksek olduğunu düşündünüz mü? Evet ise, buna neler yol açabilir? İzlenen film için yapılan orjinal miks mi ya da filmin miksi her sinema sistemine farklı mı aktarılıyor?

Bu proje, İstanbuldaki farklı sinema salonlarında gösterilen iki farklı filmin (The Avengers: Infinity War and The Cleaning Lady) algılanan ses seviyelerinde farklılıklar olup olmadığını araştırıyor ve karşılaştırıyor.

Bu sinemalar arasında ele alınan iki filmin frekans spektrumu boyunca belirgin bir ses seviyesi farklılığı görüyor muyuz? Bu ses seviyesi farklılıklarını her farklı sinema salonu analizlerini karşılaştırarak ispat edebiliyor muyuz? Bu projedeki ana odağımız ve sorularımız bu yöndedir.

Bir ses mühendisi olarak, bu konuya önce elde edilen verileri analiz ederek yaklaştım. Ayrıca, izleyici olarak sonuçları kendi kişisel çıkarımlarımla karşılaştırdım. Bunun için, İstanbul'da 4 farklı sinema salonu ve iki farklı film türünün ses seviyesi farklılıklarını ölçtüm ve karşılaştırdım. Bu karşılaştırmayı yapmak için 2 farklı ses basınç gücü ölçüm cihazı kullandım: Bir tanesi, kendi üzerinde ölçüm mikrofonu olan profesyonel taşınabilir ses analiz cihazı (Phonic PAA2) ve diğeri ise akıllı telefon (iPhone 6S) üzerinde çalıştırılan profesyonel ses ölçüm aplikasyonu (Decibel x Pro). Her iki cihaz bütün ölçümlerde aynı spesifik açıyla konumlandırıldı ve sonuçları daha sonra karşılaştırıldı.

Bu projenin çıkarımı, farklı ses teknolojisi, format ve akustiğe sahip 4 farklı sinema salonunun ses basinç gücü farklılıklarının karşılaştırılabilir olduğunu kanıtlamaktır.

Yaptığım analizlerin sonucuna bakınca, bu dört farklı sinemanın her birinin karakteristiği sebebiyle, algılanan ses basınç gücünde kavranabilir bir farklılık göstermiştir. Aynı zamanda farklı film tarzlarının da algılanan ses basınç gücünün dinamiğine etki ettigi, muhtelif teknolojilere sahip türlü sinema salonlarının gözle görülür farklılıkları olduğu ispat edilmiştir.

1. INTRODUCTION

Loudness consists of measurable qualities of sound: minimum, average and maximum SPL (Sound pressure level) which is measured as decibel (dB). As Harry F. Olson puts it: " Loudness depends primarily upon sound pressure but it also depends upon frequency and waveform of the stimulus. The units on the scale of loudness should agree with common experience estimates about the magnitude of the sensation. The measurement of loudness is a significant part of the audio art because the loudness of a sound or noise plays an important role in the reproduction of sound" (Olson, 1972, p.18). The perception of the loudness differs in accordance with many external factors such as location. According to the place that we are in, sensation of hearing and basic loudness measurements will change by this condition. There are some specific stages for how the human ear perceives the loudness. Moore et. al (1997) describes these stages as:

> A loudness model for steady sounds is described having the following stages: 1) a fixed filter representing transfer through the outer ear; 2) a fixed filter representing transfer through the middle ear; 3) calculation of an excitation pattern from the physical spectrum; 4) transformation of the excitation pattern to a specific loudness pattern; 5) determination of the area under the specific loudness pattern, which gives overall loudness for a given ear; 6) summation of loudness across ears. The model differs from earlier models in the following areas.

With the guidance of these definitions, this paper aims to investigate perceived loudness differences across different movie theaters in İstanbul.

1.1 Purpose of Thesis

Loudness measurements differ in broadcasting and cinema industries. Each movie theater has different acoustic features and sound quality, so this study aims to analyze the perceived sound pressure level differences across various movie theaters in İstanbul. Analysis of the loudness values revealed by comparing sound pressure

levels. (SPL) However, trailers and commercials that are represented to the audience before the movie starts also have a major loudness distinctness.

1.2 Methodology

Four different movie theaters were chosen to measure the sound pressure levels. Four different Cinema formats had taken into consideration (IMAX, MPX, 3D and 2D Technology). Each of the different digital cinema formats have the unique sound technology standards and sound pressure levels for each theater, so the comparison indicates the results in four digital cinema technologies. First selected movie theater is Akasya Cinemas which has IMAX Technology, second is Emaar Cinemas which has MPX Technology, third is Atlas Cinemas which has 2D and Dolby Stereo (Analog, one of the oldest cinema technologies in İstanbul), fourth is City's which has 3D Technology.

Sound pressure levels also change due to dynamic range and momentary loudness parameters in movie theaters. In addition, two different movies were chosen and they have different genres such as action and thriller which are showing on selected four different movie theaters. For instance, an action movie involves high dynamic range and low and high frequencies are more intense than the thriller, which will be compared and explained with frequency spectrum diagrams in the following chapters.

1.2.1 Recording process and positioning

The analyzing equipment used is Decibel X Pro application running on iPhone 6S mounted on atripod stand for stabilization purposes, which is then calibrated in relation to the PHONIC Personal Audio Assistant 2.1 (PAA2) that comes with a built-in omnidirectional condenser measurement microphone. In the calibration process, each of the devices' microphones is positioned 1 meter away and with 45 degrees angle pointing to the three-way reference monitor (Focal Twin 6). 1 kHz signal then fed to the devices (-18 dB @1 kHz, @1 meter). By using decibel Decibel X Pro's calibration trim function, Decibel X Pro boosted to +5.1 dB as initial level.

There are a number of weighting methods in the sound measurement system which consist of A(dBA), C(dBC) and Z(dBZ).

Decibel X Pro is an iPhone application that has pre-calibrated measurements which have 3 commonly used frequency weighting filters: A(dbA),C(dbC) and Z(dbZ).

'A' Weighting is standard weighting of the audible frequencieswhich is generally used for the noise measurements. 'A' weighting cuts off the lower and higher frequencies like the human ear which is not capable of hearing the low and high frequencies. However, the ear is more sensitive between 500 Hz and 6 kHz. Therefore, the A-weighted value of a noise source is an approximation to how the human ear perceives the noise. It is generally shown as dB(A) or dBA.

Here is the A-weighted frequency response graph in Figure 1.1:

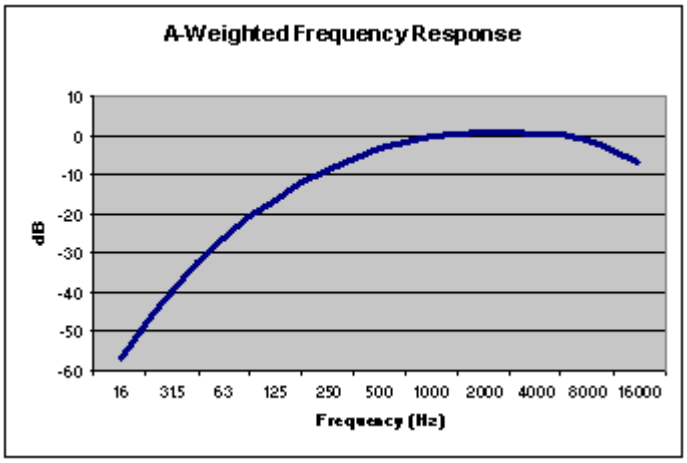

Figure 1.1 : A-Weighted Frequency response (Url-4).

'C' Weighting is a standard that is commonly used for the measurement of Peak Sound Pressure level. (PSPL). The frequency response is flatter than the A-weighting.

The 'C' weighting are shown as dB(C). dB(C) is the optimum weighting standard for analyzing the SPL differences in the movie theaters so that it is used this weighting mode in this project. Here is the C-weighted frequency response graph in Figure 1.2 below:

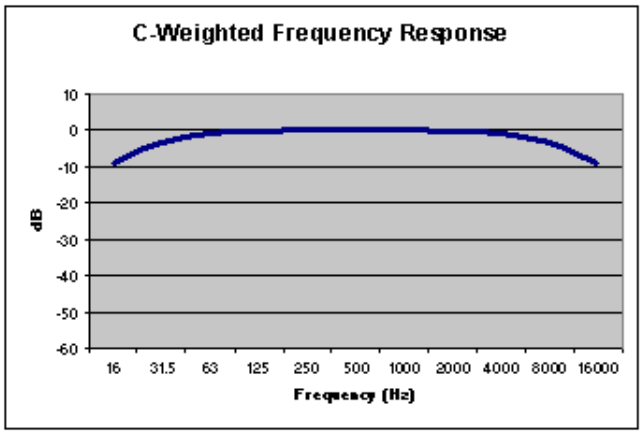

Figure 1.2 : C- Weighted Frequency response (Url-4).

Z weighting has a liner/flat frequency response between 10 Hz and 20 kHz. It is commonly used in conjunction with octave band filters. The 'Z' weighting are usually shown as dB(Z). B weighting which is not commonly used adjust the average human hear between 50dB and 90 dB.

Here is the A, B and C Weighting functions as a graph in Figure 1.3 below:

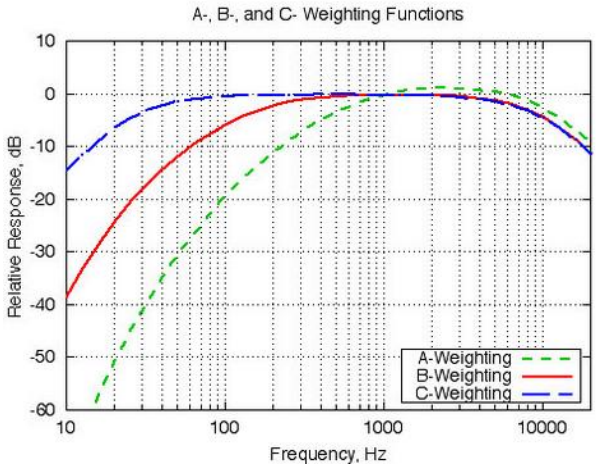

Figure 1.3 : Frequency Weighted for A, B and C Weightings (Url-9).

Decibel X Pro is an application with various advantages, which has a wider array of parameters for analysis than any other app. Firstly, it can easily calibrated with the PAA2 Audio Analyzer. Trimming calibration capacity is from -15 dB to 15 dB and standard measurement range is from 30 dB up to 130 dB. In addition, it has a quite useful option for long duration recording "Keep Device Stay Awake" which was very handy for this specific analysis. Here is a simple look of the Decibel X Pro app in Figure 1.4 below:

Figure 1.4 Decibel X Pro Application.

As it's seen in Figure 1.4, the interface of the Real Time Analyzer is on the top and the average, current and the maximum SPL values are displayed at the bottom of the screen. Also, it has a saved list of history data which can be stored into history records. The history records can also easily be exported as high resolution graph or CSV text of the analysis. As well as keeping the SPL history records, it also calculates Time-Weighted Average (TWA) and Dose values which determines a noise exposure for a noise dose. (E.g work environment noise levels, audio pollution).

Each device’s microphones are positioned with 45 degrees on axis pointing to the screen. Seat positioning of devices are set on the center of each movie theater to get optimal sensual perception. You can see the general view of the positioning of PAA2 Real Time Analyzer and Decibel X Pro Application on iPhone in Figure 1.5 below:

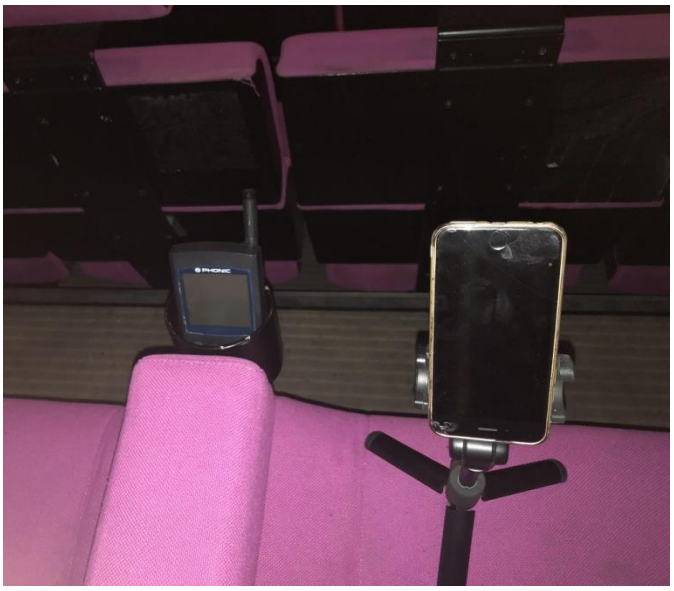

Figure 1.5 : Recording Position of PAA2 RTA and Decibel X Pro App.

Phonic Personal Audio Assistant 2.1 (PAA2) which is the second SPL meter device that is used for the analysis also have 3 different frequency weighting filters: A(dbA), C(dbC) and Z(dbZ).

Here is a simple look at the PAA2 Audio Analyzer device in Figure 1.6 below:

Figure 1.6 : PAA2 Audio Analyzer (Url-9).

Phonic Personal Audio Assistant is an audio analyzer tool that analyze both frequency spectrum and Sound Pressure Level (SPL). It is usually used for live performances to analyze the acoustic resonance of the venue by using the frequency spectrum analyzer, as well as for measuring SPL values throughout Public Address (PA) systems, venues, cinemas and other various applications requiring SPL metering. PAA2's measurable range is from 30 dB to 130 dB. It has 10 memory slots to store the max SPLs in each 31-band frequency spectrum so it can be recalled and checked back for the results after the analysis (Url-7).

A bar-chart has been made from the results of the analysis by using the PAA2's 31-band frequency analyzer. You can see the basic interface of the Real time analyzer (RTA) in Figure 1.7 below:

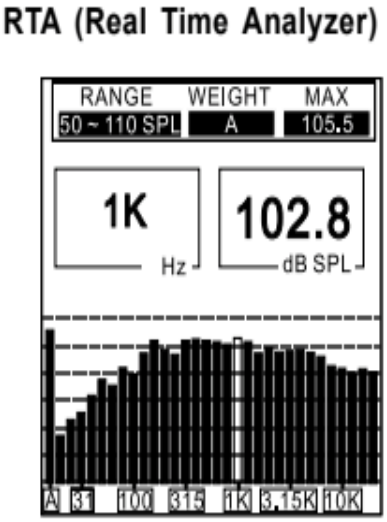

Figure 1.7 : PAA2 Real Time Analyzer (Url-9).

Phonic Personal Audio Assistant has a startup process which is about 10 seconds after you switch it ON, then the real time analyzer starts analyzing instantly using the spectrum analyzer. Level range, weighting type, and max level are displayed on the screen in PAA2 Real Time Analyzer (RTA) mode.

1.3 Literature Review

In the past years, the cinema sound technology advanced gradually according to expectations. Movies' sound were recorded on many different types of media in different formats.. The movie theaters were made generally converted from amphitheaters and soundtracks were mixed with almost the same used equipments such as similar size and sound speakers. The background noise (hiss) had been an important issue in recording process. Because of these limitations, recording mixers and producers have kept the soundtracks simple. Even though various types of recording equipment with better quality has been introduced to the media, it costs much in the production. In the early 1970s, solving these problem, Dolby Laboratories released an A-type noise reduction system to cinema soundtracks.

1.3.1 History of cinema sound from Vitaphone to Magnetic recording systems

There was Vitaphone, an analogue recording system, which was using sound on disc method before the digital recording on cinema was invented.This analogue sound recording was synced in real time with projection after the movie was filmed. Vitaphone method first used in the "Don Juan" movie which had synchronized music and effects but no dialogue in 1926s. Vitaphone method is also used in "The Jazz Singer", which is exhibited in New York City in 1927 October 6th, which consisted of a record player playing a wax record and a Vitaphone score that contains the singing and speech, was then synced to the moving picture."The Jazz Singer" was known as sound-on-disc. The sound recording was usually done after the movie was filmed. The record was played on a turntable that synchronized sound to the film by controlling the speed of the projector. It was a simple but very effective way to add audio to a movie. (Tyson, N.d).Vitaphone system was quite difficult with the wax discs to shoot outdoors or to edit sound.

In the early 1930s, sound on film method which is a class of sound film processes where the sound accompanying a picture is physically recorded onto photographic film began to be used in motion picture. There was a disadvantage of the sound on film that had been a distortion of the signal when recording the soundtrack. It uses Optical and Magnetic technologies. Optical sound is a sound on film format for motion pictures and also used for multitrack recording and musical synthesizers (Url-2). The most common method is an optical process whereby a transparent line is

recorded along one side of the film. This strip varies in width according to the frequency of the sound. For this reason, it is known as a variable-area soundtrack. As the film passes the audio pickup, an exciter lamp provides a bright source of light, focused by a lens through the transparent line. The light that passes through the film shines on a photocell (Tyson, n.d).

In the 1950s,magneticrecording became popular. Magnetic sound-on-film had a couple of advantages over optical at the time and there are many comparisons such as stereo- mono, better or worse sound quality, cheaper or more expensive. You can see the magnetic recording flow below in Figure 1.8:

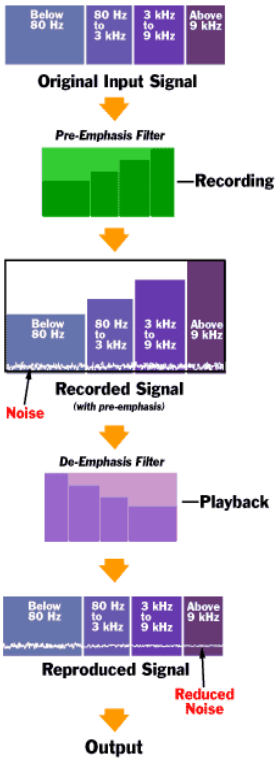

Figure 1.8 : Magnetic recording flow (Tyson, n.d).

1.3.2 History of surround sound

In the early years, audio recording techniques for movies was quite insufficient and you can hear a disturbing amount of background noise hiss in tape recordings. Dolby Laboratory has developed a specific noise reduction technology to prevent these audio quality problems and furthering the science of audio and video productions (Url-8).

In addition to this, audio specialists had been trying to expand the space and width in recorded sound. Although reverbs, delays and spatial effects provide sense of space, they are not able to satisfy the regular human hearing capability.

To fulfill this gap, surround sound, which improves sound localization, better psycho-acoustics as well as the system's dynamic range and tonality, is introduced for the cinema industry. In April 1933, first using three speakers; left- right - center is introduced to cinema industry. Walt Disney's Fantasia (1941) was the first motion picture which has used on surround sound. In 1950, Disney used Fantasound technology which creates a surround sound field with each left front, center front, right front, left rear, and right rear channels (Url-3). Dolby stereo sound which is an optical four channel technology released by Dolby Laboratories in the 1976.

First movie that used Dolby noise reduction was "The Clockwork Orange" which influenced theater owners to upgrade their sound systems to the Dolby Stereo standards in 1971. Specially, Star Wars movie which brought a quite big success is released with its swooping rear-channel effects in 1977. Many other movies then adapted to the Dolby Stereo system throughout the 1980s.

Micheal Miller (2004) enucleated Dolby Spectral Recording (SR) and THX technology in his article below:

> In 1983, Lucasfilm introduced THX certification (named after George Lucas' first film, *THX 1138*), a set of technical standards designed to ensure a high-quality playback of film soundtracks in specially equipped movie theaters. In 1987, Dolby introduced *Dolby SR*, an optical four-channel system that offered wider dynamic range and a broader frequency response than the previous Dolby Stereo system.

In those years, surround sound technology started to get used incrementally and had many difficulties such as format incompatibility issues between movies vs the theaters. Producers tried each different progressive formats to add the latest version of the digital sound format in their films although the capability of movie theaters were insufficient to convey optimum sound to the audience.

In 1987, when a subcommittee of the Society of Motion Picture and Television Engineers (SMPTE) announced the 5.1-channel system as being the minimum number of channels that would create the sensations required for the surround sound.

5.1 Surround system consists of 6 speakers: Center (C), Left (L) and Right (R) at angles of 60° on either side of the center, Left Surround (LS), Right Surround (RS) at angles of 100–120° and Subwoofer which is used for low frequency effect (LFE).

After Dolby Digital multichannel film sound format was introduced, the name "Dolby Surround" replaced with "Dolby Digital". "Batman Returns" was the first Dolby Digital Surround movie in 1992. Here is a basic explanation of a standard stereo set up vs a surround set up in Figure 1.9 below:

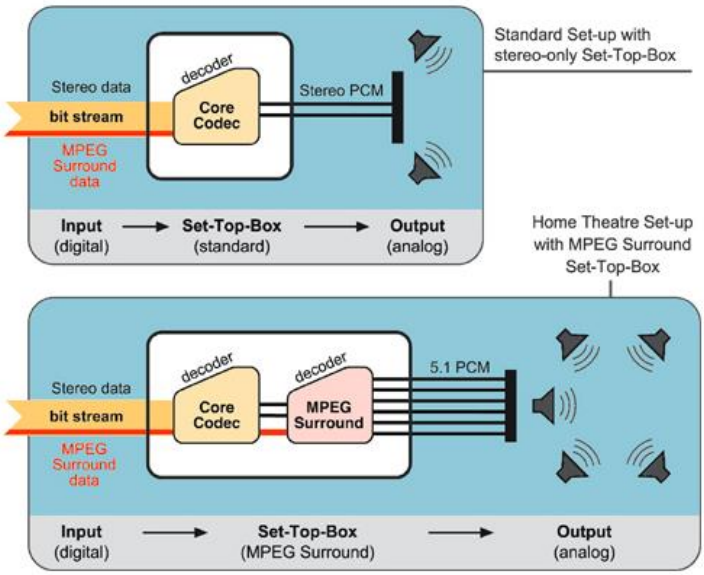

Figure 1.9 : Processing Stereo system vs. Surround System (Andry, 2009).

Digital Theater Systems company released DTS Surround Sound Technology which is similar to Digital 5.1 channel systems. It recorded the audio channels on CD and audio information transferred with higher quality than the Dolby Digital Surround. The First used Digital Theater Systems technology was the Jurassic Park in 1993s.

Dolby Digital EX and Dolby Digital Plus technology adds one or two matrixed rear channels to the Dolby Digital Surround system so it is to be used 6.1 and 7.1 sound systems. The first EX movie was "Star Wars: Episode One- The Phantom Menace" in 1999. The first Dolby Atmos which has quite a depth, reality, clarity, mixed with moving audio, 360 degree sound perception and high quality sound processors is released in 2012 at Dolby Theater, Los Angeles. It has totally 128 audio tracks which can be assigned to each audio channel. It uses 9-1 bed channel, 118 tracks assigned for music and effects and 10 channels assigned for ambience stems or center

dialogues. Dolby Atmos also has been used in home theaters for the consumers as Dolby Cinema since 2013 (Url-12).

1.4 Loudness Standards for Europe

In the past years, the analogue TV broadcasting used with the stereo tracks yet the loudness war has not become. When the broadcasting companies tried to achieve the highest possible level ignoring to ruin the audio fidelity and dynamic range, it caused the "Loudness Wars" that is built with "Louder is better" idea.To prevent these consistencies of the loudness levels on the broadcast, The European Broadcasting Union (EBU) committee decided to deliver a standard for the loudness levels in production, distribution and transmission of broadcast programmes. It is of the opinion that an audio-levelling paradigm is needed based on loudness measurement. EBU decided that the 'Loudness Range' and 'Maximum True Peak Level' measures should be used for the normalisation of audio signals with the essential limits of the complete signal chain as well as the aesthetic needs of each programme or station.

The EBU R128 standard consists of 4 tech documents: EBU Tech 3341, EBU Tech 3342, EBU Tech 3343 and EBU Tech 3344. The recommended loudness is -23 LUFS/LKFS. Different broadcasting organizations have a different approach to loudness levels. So there are various standards accepted by broadcasting communities throughout the world. The International Telecommunication Union's (ITU) BS.1770 algorithm is used for measuring audio programme loudness and true peak audio level. It is recommended to loudness standards between different countries by the technical committee. This Recommendation specifies audio measurement algorithms for the purpose of determining subjective programme loudness, and true-peak signal level.

The ITU standard is a global recommendation and many other broadcast standards are based on it. Loudness measurement of the ITU based on Leq which is the equivalent continuous Sound Pressure Level in dB. Leq is measured with K weighting which is developed by the Communications Research Centre, Canada. The ITU BS.1770 algorithm is lastly updated to ITU.BS.1770-3 version in 2012 (Url-13).

Loudness level differences between places or programs which is self-contained audio-visual or audio-only item to be presented in Radio, Television or other

electronic media. For instance, the updated (2018) audio loudness standard for BBC channel is -18 LUFS, for Amazon Echo/Alexa (Smart Speakers range introduced by Amazon) and Spotify channels are -14 LUFS, for ATSC A85 (US TV) channels NPRSS & PRX are -24 LUFS. These loudness values referring to short term and long term peak values, therefore, it is aimed not to exceed these standards.(Tepper, 2018). However, these loudness level differences in these areas caused many problems because inconsistent low and high loudness levels discomfort to the audience.

Commercial advertisement loudness mitigation (CALM) act is made to prevent and control these loudness differences between commercials for broadcasters. The CALM act aims to balance these to the same levels by using dynamic range compressors, so the audience won't be exposed to those disturbing inconsistency (Url-6).Each platform, such as TV, radio, internet, podcasts, and other personal entertainment systems, has its own requirements for dynamic range, frequency range and speech intelligibility, so more automated handling is simply a necessity (Lund, 2006).Thomas Lund measured the typical background noise levels in Table 1.1 below:

Table 1.1 : Typical noise levels measured by Thomas Lund (Lund, 2006).

	SPL A weighted	SPL C weighted
Living Room, Suburban	45 dB	
Living Room, Urban	55 dB	70 dB
Inside Car	65 dB	85 dB
Inside Jet	75 dB	90 dB
Walk in Traffic	80 dB	92 dB
Subway	90 dB	100 dB

He showed that people are exposed to different loudness levels in different places. I also questioned how loudness differs and sound levels reacts on different movie theaters in my analysis.

2. LOUDNESS MEASUREMENTS OF THE FIRST MOVIE

First selected movie for the analysis is “The Avengers: Endgame”. I chose this movie because it is an fantastic/action movie so that it has many special effects throughout the scene. I analyzed this movie in 4 different movie theaters in İstanbul which are City’s Cinemas, Akasya Cinemas, Atlas Cinemas and Emaar Square Mall.

2.1 Theater #1: City’s Cinemas

City’s movie theater located in City’s Cinemas which consists of 7 theaters in total. The capacity of these theaters and number of the seats changes by each room. Theater 1 which is called “Orange room” has 68 seats and it is the smallest room of the City’s movie theater. Theater 2 and Theater 4 have 78 seats which are called “Green Room” and “Blue Room”. Theater 5 and Theater 6 are also the same number of seats that are called “Green 2 Room” and “Orange 2 Room”. They are also smaller than the other rooms. Theater 3 which is called “Red Room” has 174 seats. This room is the second largest room in the City’s movie theater. Theater 7 has 263 seats and it is the largest room in the City’s movie theater. It is called “Golden Room”.

The second movie selected was screening on Theater 3 so this theater has chosen for the analysis. The selected seat number is F-8. You can see the general view of the City’s Cinemas theater 3 in Figure 2.1 below:

Figure 2.1 : Overview to City’s Cinemas Theater 3 (Url-5).

The selected seat in City's Cinemas seating plan is marked as X in Figure 2.2 below:

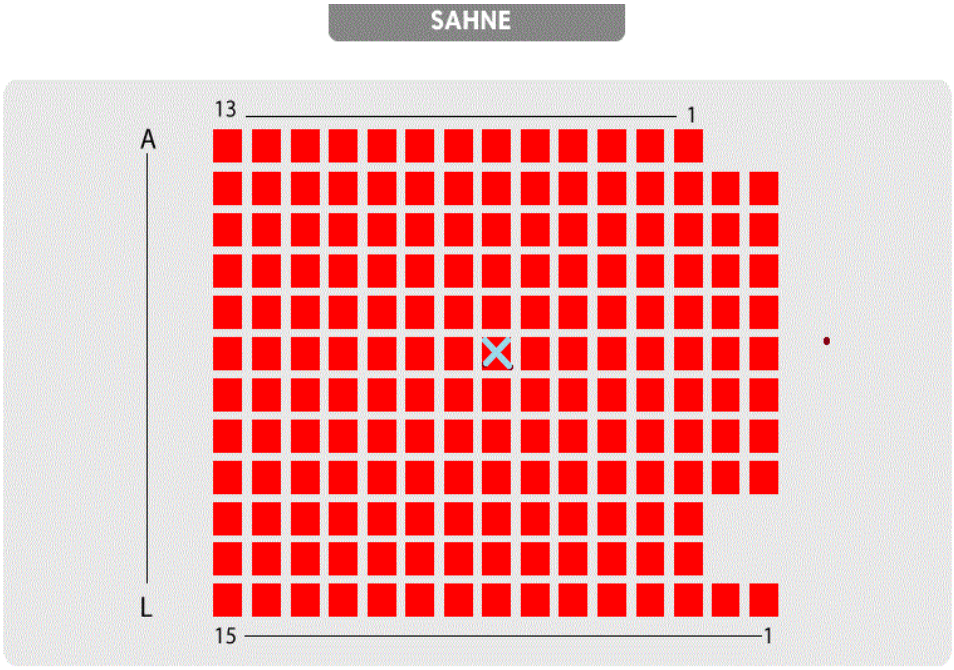

Figure 2.2 : Seating plan in City's Cinemas Theater 3 (Url-10).

2.1.1 SPL Values and Spectrum Analysis of Theater #1

The first 25 minutes of "The Avengers-End Game" analyzed with PAA2 on City's Cinemas Theater 3. Results are indicated maximum SPL value on each frequency and prepared as a chart in Figure 2.3 below:

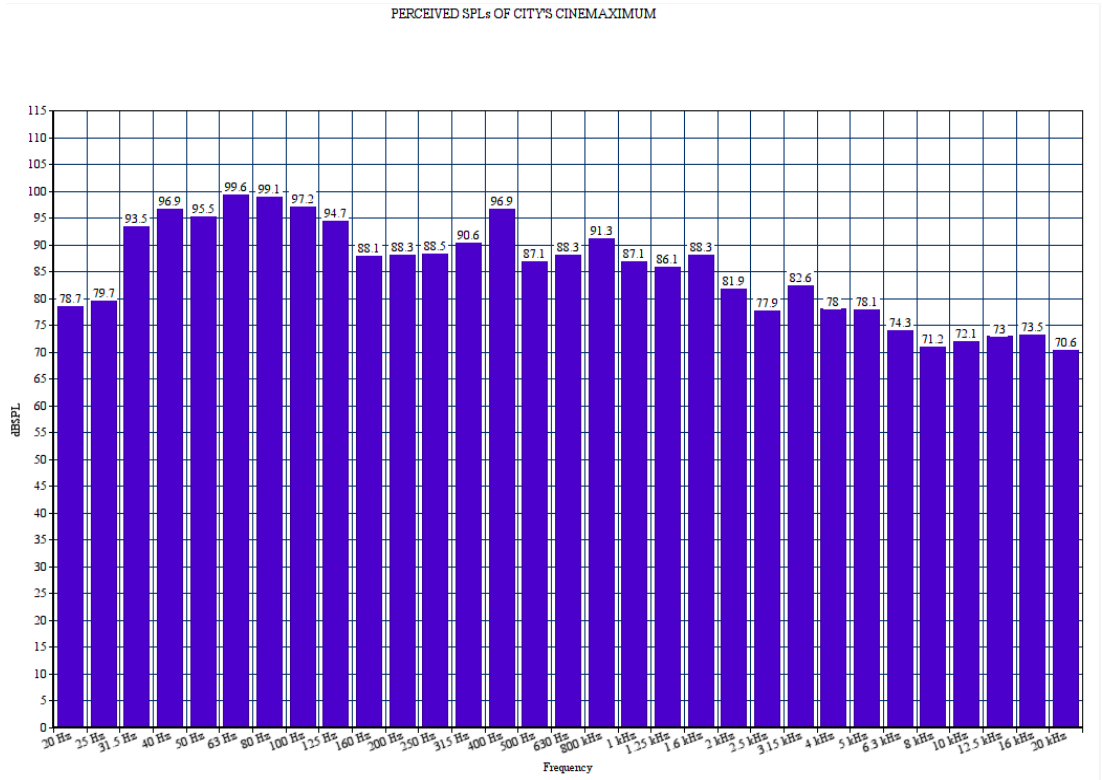

Figure 2.3 : PAA2 Frequency vs. SPL chart of City's Cinemas Theater 3.

All results of PAA2 device are prepared as a chart. The name of the X axis indicates 'Frequency' and the name of the Y axis indicates 'dBSPL'.

As it's seen in Figure 2.3, maximum level of the sound pressure level is on 63 Hz, 99.6 dBSPL, minimum SPL is on 20 kHz, 70.6 dBSPL. Both devices were set to C Weighting. Decibel X Pro Sound Pressure analysis of 'The Avengers-End Game' movie scheme is in Figure 2.4 below:

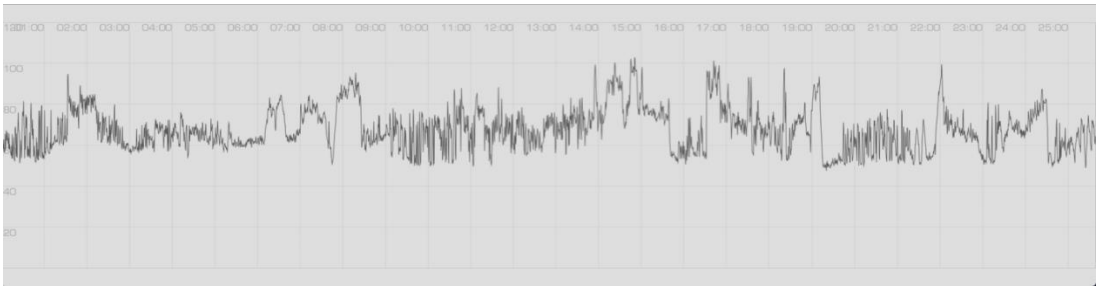

Figure 2.4 : Decibel X Pro SPL Analysis of City's Cinemas Theater 3.

Calibration was set to 5.1 dB with reference to PAA2 to get approximately close SPL values. The name of the X axis indicates ‘Time’ and the name of the Y axis indicates ‘dBSPL.

Decibel X Pro displays perceived minimum, maximum and average SPLs below:

Minimum: 47.6 dBC

Average: 82.0 dBC

Maximum: 103.0 dBC

Peak: 108.4 dBC

Dose (%): 16.1

TWA (dBC): 55.7

2.2 IMAX Technology

Akasya Cinemas has state of the art cinema sound technology and it is newer than the most Turkish movie theaters with IMAX 3D technology. It is one of the largest movie theater and sound system after Istinye Park Cinemas in Turkey. There are a total of fifteen rooms including IMAX 3D technology in Akasya Cinemas.

You can see the general view of the Akasya Cinemas Theater 3 in Figure 2.5 below:

Figure 2.5: Akasya Cinemas IMAX Theater 3.

Theater 3 shown on Figure 2.5 has the largest IMAX technology based room in the Akasya Cinemas. It is introduced as the new IMAX Technology in Turkey. The comfort of the seats and the technology satisfies the audience both visually and perceptually. Ideal listening and viewing position is on G row because the perception of transmitted sound is perceived equally by the audience when seated at the center.

Decibel X Pro and PAA2 Phonic devices are also set to the center of seats in Theater 3. The selected seat number is G-14. The selected seat in Akasya Cinemas seating plan is marked as X in Figure 2.6 below:

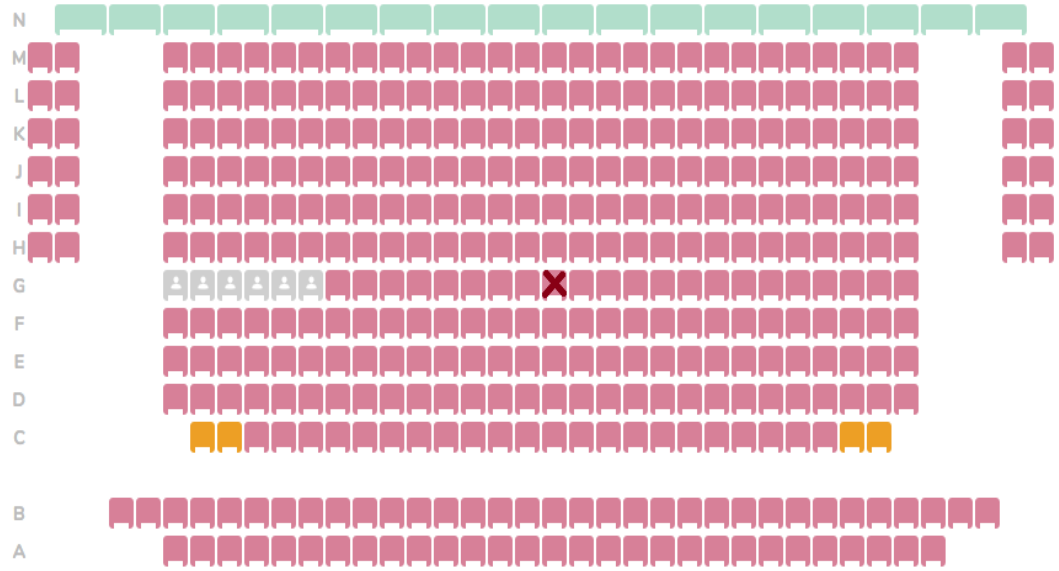

Figure 2.6 : Akasya Cinemas IMAX Theater 3 Seating Plan (Url-10).

2.2.1 IMAX Technology

IMAX Cinema Technology is a new format that generically called "15/70" film and it consists of high-resolution film and sound formats, cameras, film projectors and theaters known for having very large screens systems. Graeme Ferguson, Roman Kroitor, Robert Kerr, and William C. Shaw are the co founders who established IMAX Corporation in 1967. IMAX theater systems were installed in many commercial multiplexes in most countries with less than a quarter of these having the capability to show 70 mm film at the resolution of the large format in 2017s. The first 3D film which is “We are Born of Stars” was released in Japan in 1985 and

IMAX Corporation won the Academy Award for scientific and technical achievement in 1997.

2.2.2 SPL Values and Spectrum Analysis of Theater #2

The first 25 minutes of “The Avengers-Endgame” analyzed with PAA2 on Akasya Cinemas IMAX Theater 3. Results are prepared as a chart in Figure 2.7 below:

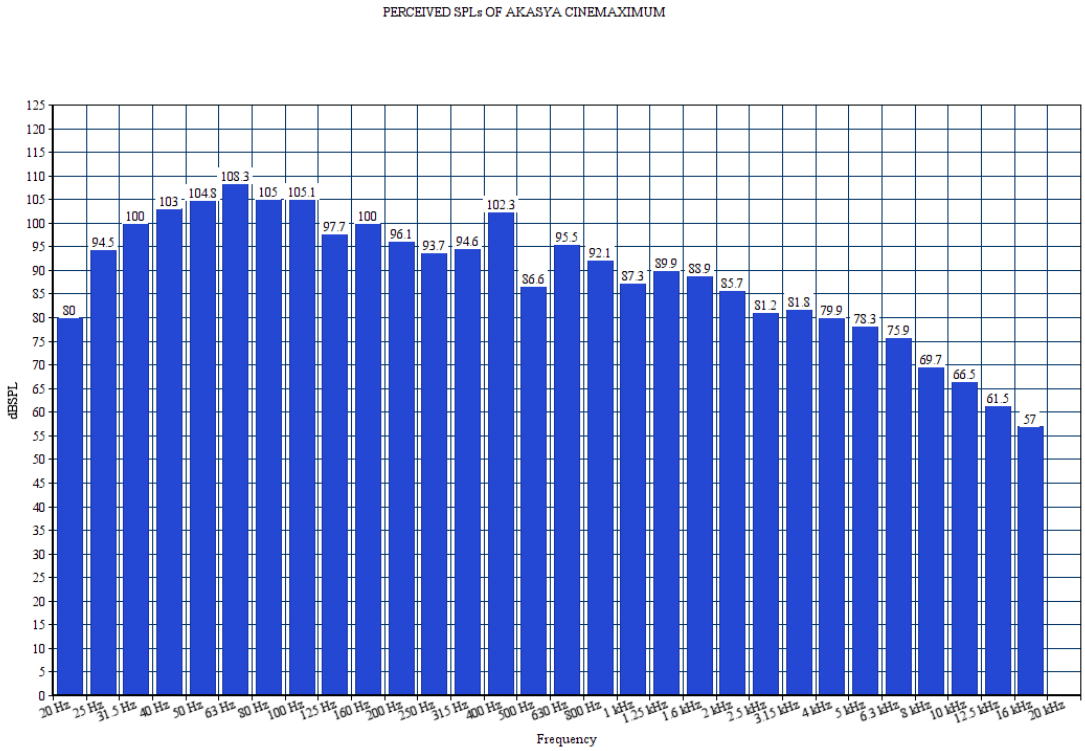

Figure 2.7 : PAA2 Frequency vs. SPL chart of Akasya Cinemas IMAX Theater 3.

All results of PAA2 device are prepared as a chart. The name of the X axis indicates ‘Frequency’ and the name of the Y axis indicates ‘dBSPL’.

As it's seen in Figure 2.7, maximum level of the sound pressure level is on 63 Hz, 108.3 dBSPL, minimum SPL is on 20 kHz, 57 dBSPL. Both devices were set to C Weighting. Decibel X Pro Sound Pressure analysis of ‘The Avengers’ movie scheme is in Figure 2.8 below:

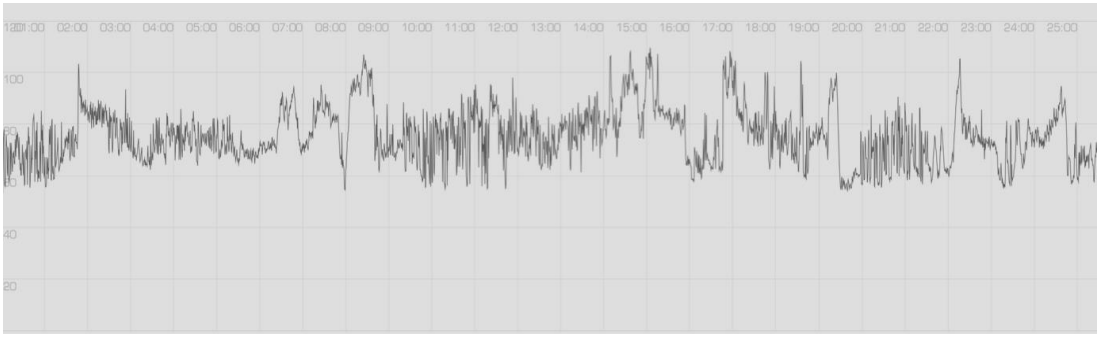

Figure 2.8 : Decibel X Pro SPL Analysis of Akasya Cinemas IMAX Theater 3.

Calibration was set to 5.1 dB with reference to PAA2 to get approximately close SPL values. The name of the X axis indicates 'Time' and the name of the Y axis indicates 'dBSPL'.

Decibel X Pro displays perceived minimum, maximum and average SPLs below:

Minimum: 51.5 dBC

Average: 89.7 dBC

Maximum: 109.6 dBC

Peak: 114.8 dBC

Dose (%): 94.4

TWA (dBC): 68.5

2.3 Theater #3: Emaar Cinemas

Emaar Cinemas has MPX, DBox and the first 4DX Cinema Technology in Turkey. The movie theater in Emaar is on the L1 floor and it has a total of 2400 seat capacity. The number of the theater that has the MPX Technology is 9, the selected seat number is G-10 which is the center of the theater. Theater 9 is larger than all the other rooms in Emaar Cinemas. You can see the general view of the Emaar Cinemas Theater 9 in Figure 2.9 below:

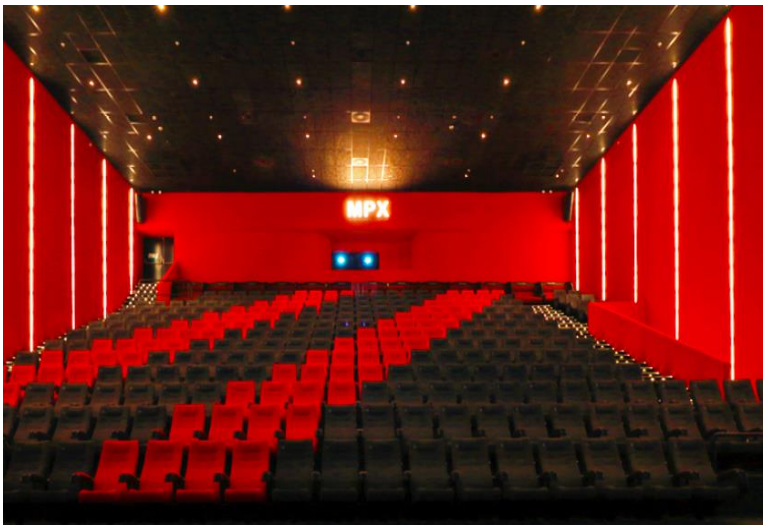

Figure 2.9 : Overview to Emaar Cinemas MPX Theater 9.

There are 4 disabled seats in front seat and 13 specious seats for couples on the back rows in Theater 9. Disabled seats are colored with yellow and double seats are colored with green in the seating plan (Figure 2.10). The selected seat in Emaar Cinemas seating plan is marked as X in Figure 2.10 below:

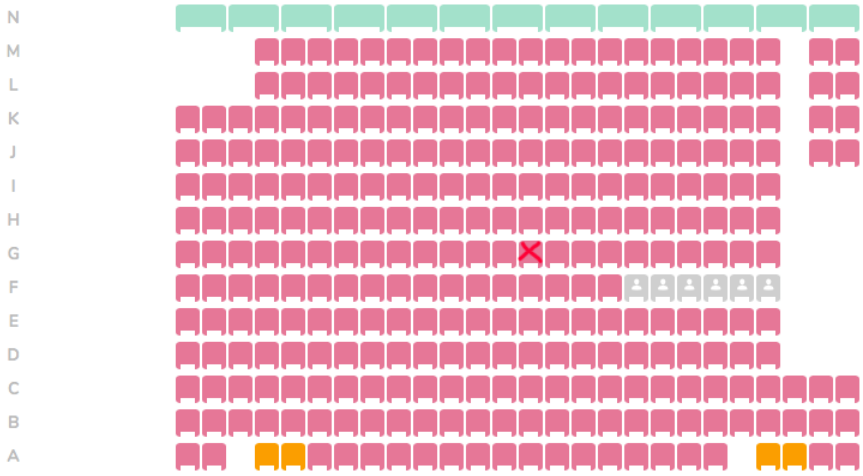

Figure 2.10 : Emaar Cinemas MPX Theater 9 Seating plan (Url-10).

2.3.1 MPX Technology in Emaar Cinemas

There are 5 theaters with Mars Premium Experience (MPX) technology in Turkey, which are Cinemaximum Cevahir, Cinemaximum Vialand, Cinemaximum Akbatı, Cinemaximum Point Bornova, Cinemaximum Emaar Square Mall. Mars Premium Experience (MPX) technology has %20 larger screen than the standard 3D cinema

technology. It provides high pixel resolutions and better sound quality. Emaar Cinemas Theater 9 was chosen for the analysis.

2.3.2 SPL Values and Spectrum Analysis of Theater #3

The first 25 minutes of "The Avengers-End Game" analyzed with PAA2 on Emaar Cinemas MPX Theater 9. Results are prepared as a chart in Figure 2.11 below:

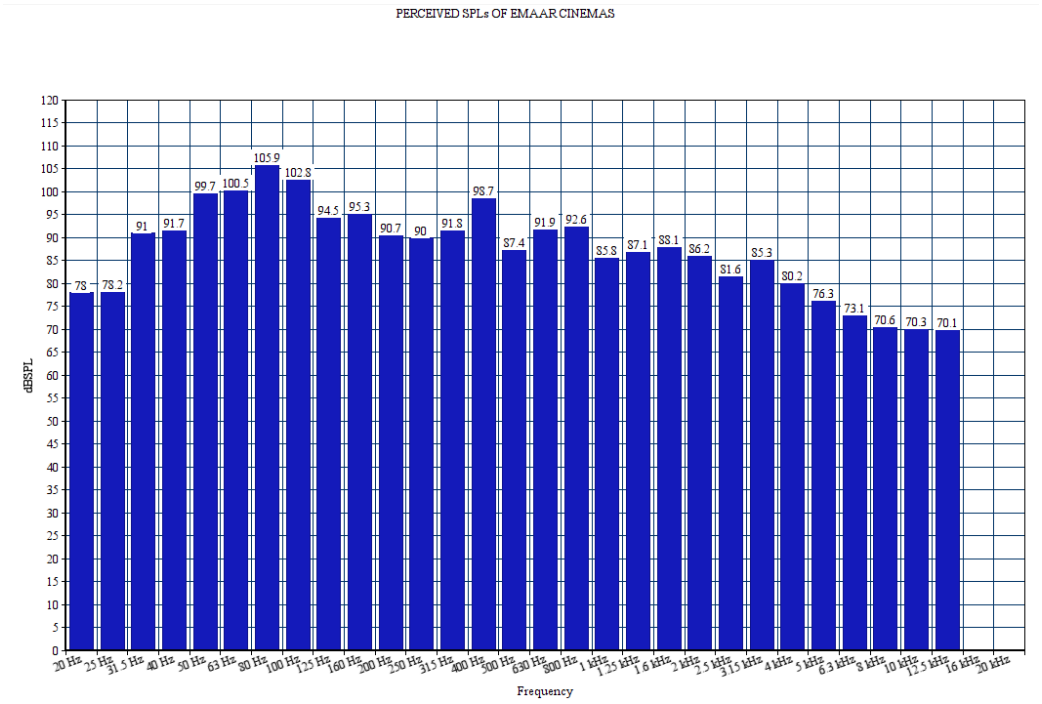

Figure 2.11 : PAA2 Frequency vs. SPL chart of Emaar Cinemas MPX Theater 9.

All results of PAA2 device are prepared as a chart. The name of the X axis indicates 'Frequency' and the name of the Y axis indicates 'dBSPL'.

Maximum level of the sound pressure level is on 80 Hz, 105.9 dBSPL, minimum SPL is on 12.5 kHz, 70.1 dBSPL in analysis of the SPLs chart. There was no data on 16 kHz and 20 kHz so it affected the average of the SPL values. Both devices were set to C Weighting. Decibel X Pro Sound Pressure analysis of "The Avengers-End Game" scheme is in Figure 2.12 below:

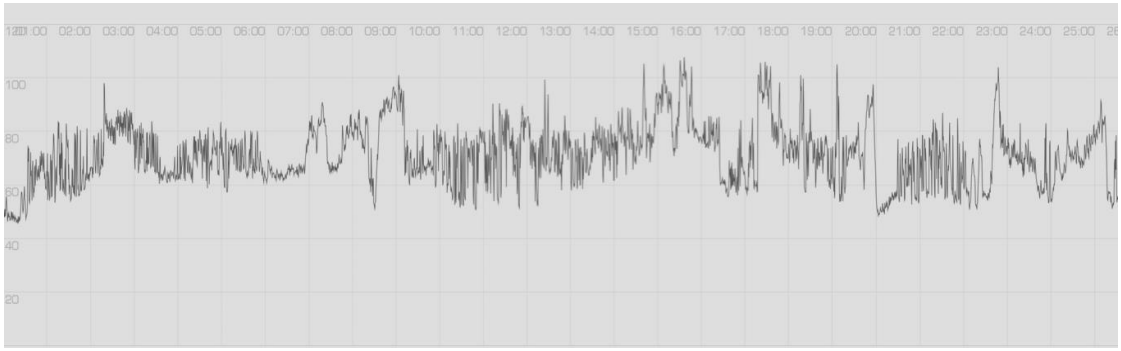

Figure 2.12 : Decibel X Pro SPL Analysis of Emaar Cinemas MPX Theater 9.

Calibration was set to 5.1 dB with reference to PAA2 to get approximately close SPL values.The name of the X axis indicates ‘Time’ and the name of the Y axis indicates ‘dBSPL’. Decibel X Pro displays perceived minimum, maximum and average SPLs below:

Minimum: 45.6 dBC

Average: 86.5 dBC

Maximum: 107.7 dBC

Peak: 113.9 dBC

Dose(%): 45.5

TWA(dBC): 63.5

2.4 Theater #4: Atlas Cinemas

Atlas Cinemas which is inside of the Atlas Bazaar is one of the oldest and largest movie theaters that is built in the 1870s in Turkey. It has 1860 capability of seats in total after the restoration in 1948. There are totally three theaters in Atlas Cinemas after the second restoration in 1985. Also, the main theater is converted from an amphitheater. Theater 1 is chosen for the analysis and the selected seat number is 9-1. You can see the general view of the Atlas Cinemas Theater 1 in Figure 2.13 and seating plan in Figure 2.14 below:

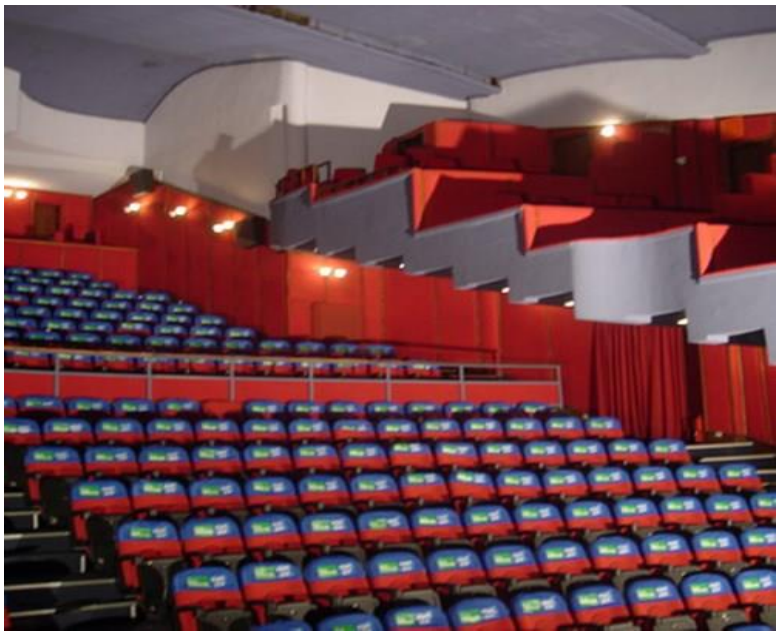

Figure 2.13 : Overview to Atlas Cinemas Theater 1.

The selected seat is marked as X in Figure 2.14 below:

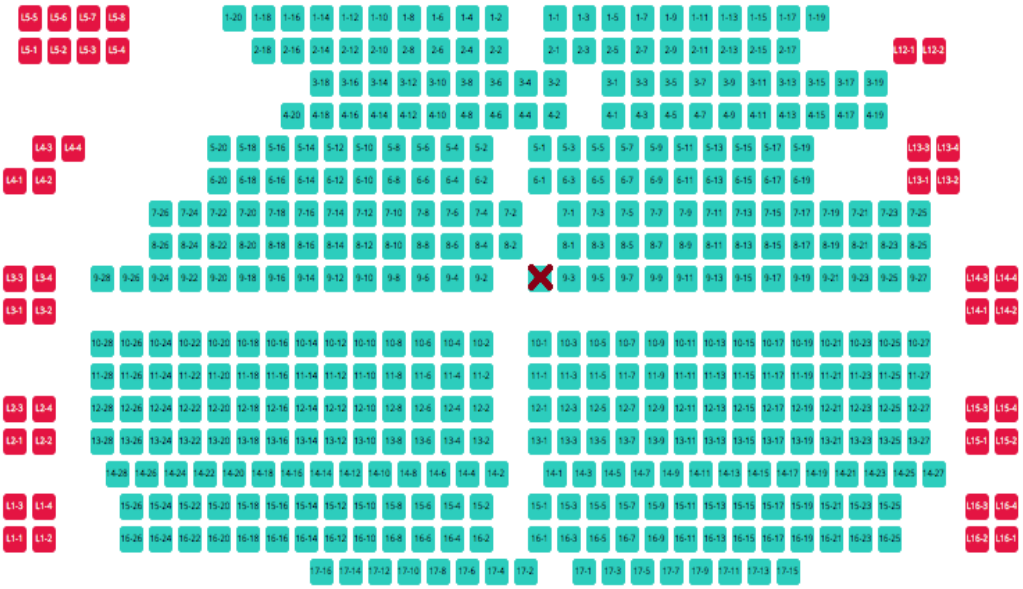

Figure 2.14 : Seating plan in Atlas Cinemas Theater 1 (Url-11).

2.4.1 SPL Values and Spectrum Analysis of Theater #4

The first 25 minutes of "The Avengers-Endgame" analyzed with PAA2 on Atlas Cinemas Theater 1. Results are prepared as a chart in Figure 2.15 below:

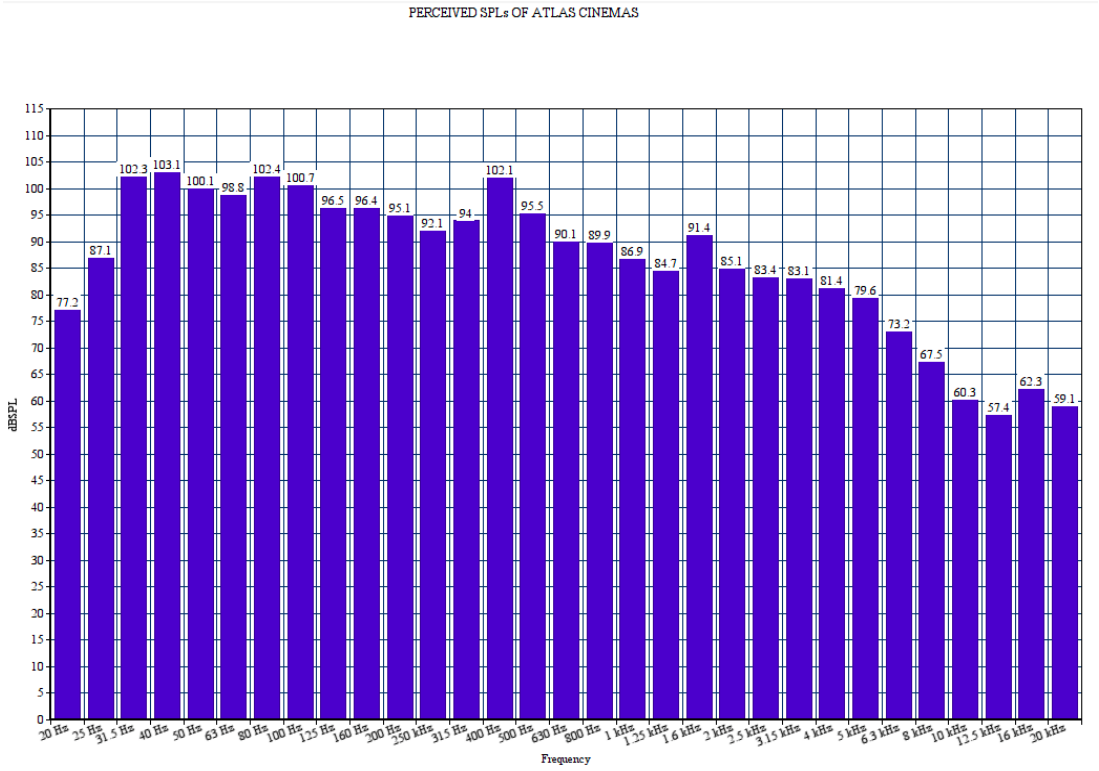

Figure 2.15 : PAA2 Frequency vs. SPL chart of Atlas Cinemas Theater 1.

All results of PAA2 device are prepared as a chart. The name of the X axis indicates 'Frequency' and the name of the Y axis indicates 'dBSPL'.

Maximum level of the sound pressure level is on 40 Hz, 103.1 dBSPL, minimum SPL is on 12.5 kHz, 57.4 dBSPL in analysis of the SPLs chart. Both devices were set to C Weighting. Decibel X Pro Sound Pressure analysis of 'The Avengers-End Game' scheme is in Figure 2.16 below:

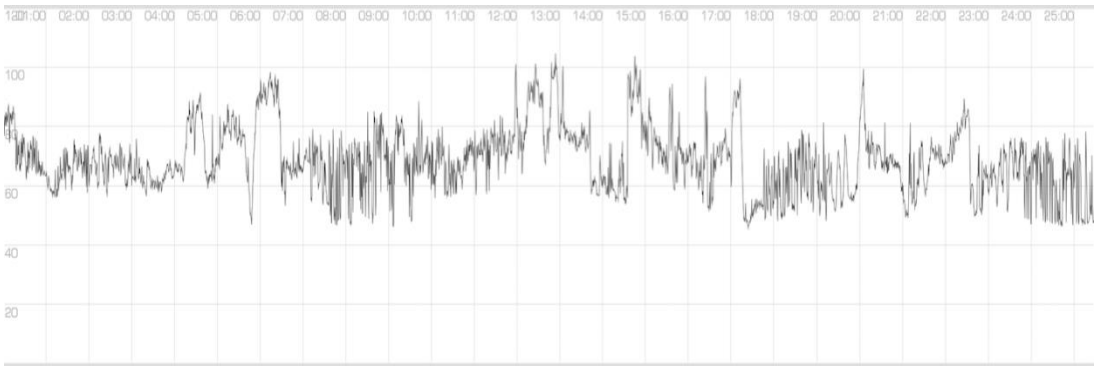

Figure 2.16 : Decibel X Pro SPL Analysis of Atlas Cinemas Theater 1.

Calibration was set to 5.1 dB with reference to PAA2 to get approximately close SPL values.The name of the X axis indicates ‘Time’ and the name of the Y axis indicates ‘dBSPL’.

Decibel X Pro displays perceived minimum, maximum and average SPLs below:

Minimum: 45.8 dBC

Average: 83.6 dBC

Maximum: 104.6 dBC

Peak: 109.5 dBC

Dose (%): 23.2

TWA (dBC): 58.3

3. LOUDNESS MEASUREMENTS OF THE SECOND MOVIE

Second movie is selected from a different genre (thriller) and it's titled "The Cleaning Lady". This second analysis aims to determine the dynamic range of the thriller movie which has a lot of momentarily changes, as in higher levels of transients which differs greatly from "The Avengers" movie. An action movie such as "The Avengers" has higher SPLs in a longer period over the scene's timeline. Whereas the "The Cleaning Lady" scenes' SPLs change from very quiet to very loud in an instant.

3.1 Theater #1: City's Cinemas

The selected second movie was played in Theater 4 which has 78 seats in total including 1 disabled seat and this theater has chosen for the analysis. Number of the selected seat is D-5.

The selected seat is marked as X in Figure 3.1:

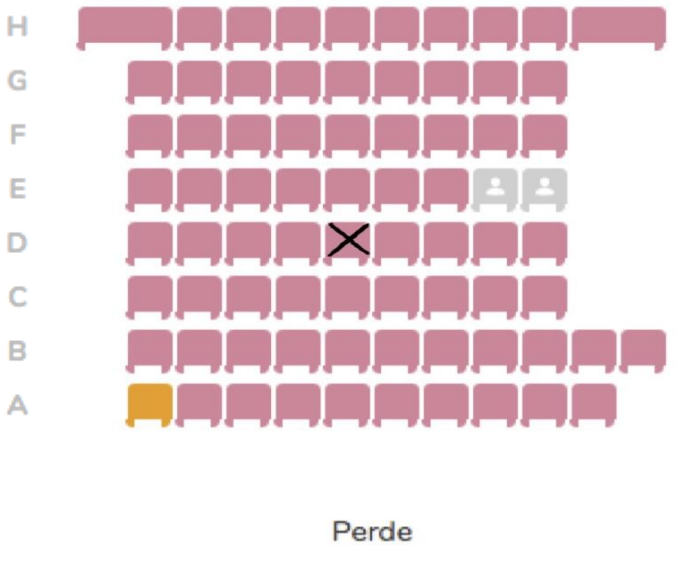

Figure 3.1 : Seating plan in City's Cinemas Theater 4.

3.1.1 SPL Values and Spectrum Analysis of Theater #1

The first 25 minutes of "The Cleaning Lady" analyzed with PAA2 on City's Cinemas Theater 4. Results are prepared as a chart in Figure 3.2 below:

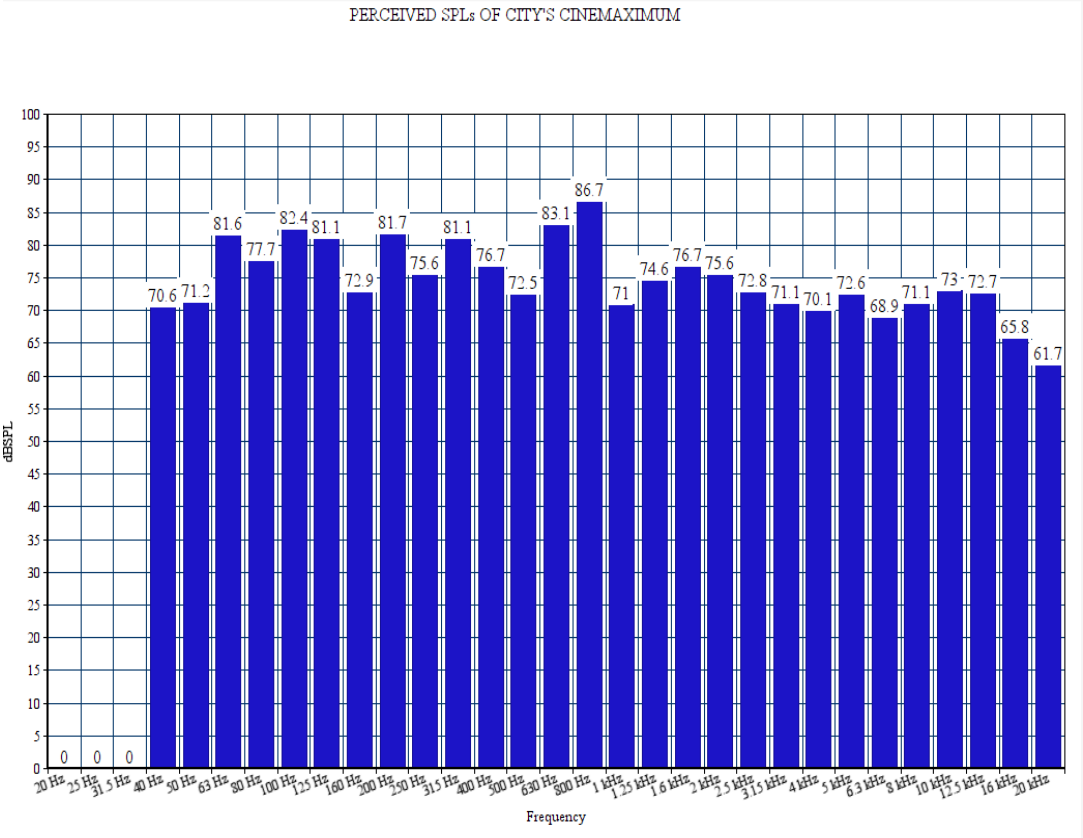

Figure 3.2 : PAA2 Frequency vs. SPL chart of City's Cinemas Theater 4.

All results of PAA2 device are prepared as a chart. The name of the X axis indicates 'Frequency' and the name of the Y axis indicates 'dBSPL'.

Maximum level of the sound pressure level is on 800 Hz, 86.7 dBSPL, minimum SPL is on 20 kHz, 61.7 dBSPL in analysis of the SPLs chart. Both devices were set to C Weighting.

Decibel X Pro Sound Pressure analysis of "The Cleaning Lady" scheme is in Figure 3.3 below:

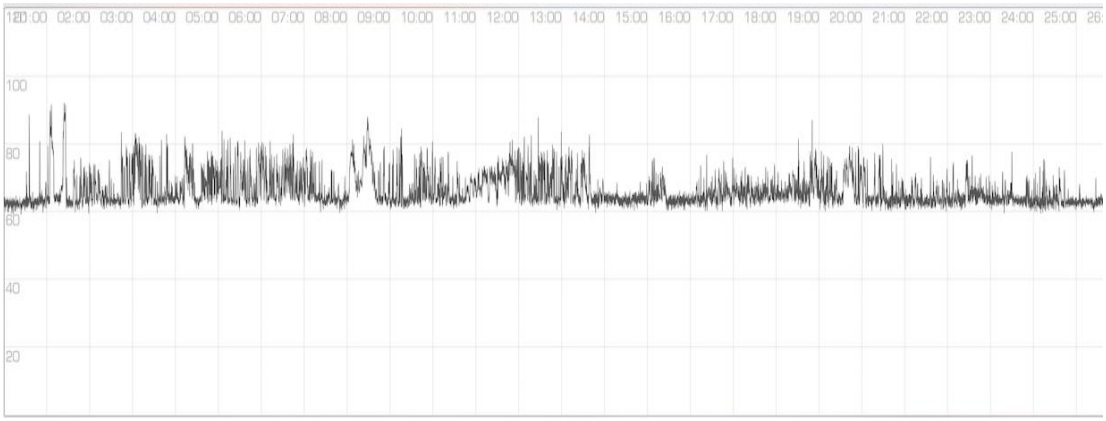

Figure 3.3 : Decibel X Pro SPL Analysis of City's Cinemas Theater 4.

Decibel X Pro displays perceived minimum, maximum and average SPLs below:

Minimum: 59.0 dBC

Average: 70.9 dBC

Maximum: 92.3 dBC

Peak: 95.9 dBC

Dose (%): 1.4

TWA (dBC): 53.9

3.2 Theater #2: Akasya Cinemas

The second movie selected was screened on Theater 10. It was not screened with the IMAX technology in any of the theaters for this movie, so it this theater 10 has been chosen for the analysis. Theater 10, which is smaller than the other rooms in Akasya, has 77 seats in total and 1 disabled seat. Number of the selected seat is D-6.

The selected seat is marked as X in Figure 3.4 below:

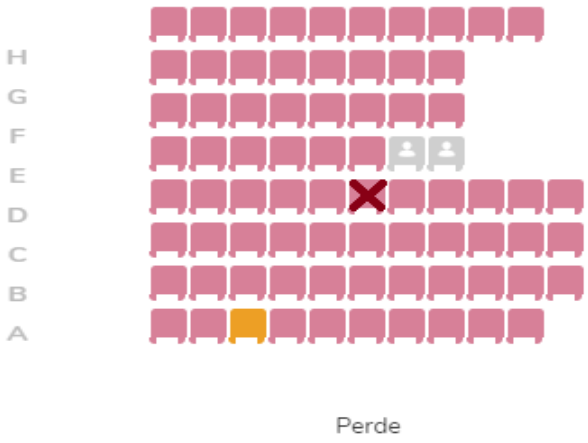

Figure 3.4 : Seating plan in Akasya Cinemas Theater 10 (Url-10).

Akasya Movie theater 10 was smaller than the other rooms and it has 1 disabled seat.

3.2.1 SPL Values and Spectrum Analysis of Theater #2

The first 25 minutes of "The Cleaning Lady" analyzed with PAA2 on Akasya Cinemas Theater 10. Results are prepared as a chart in Figure 3.5 below:

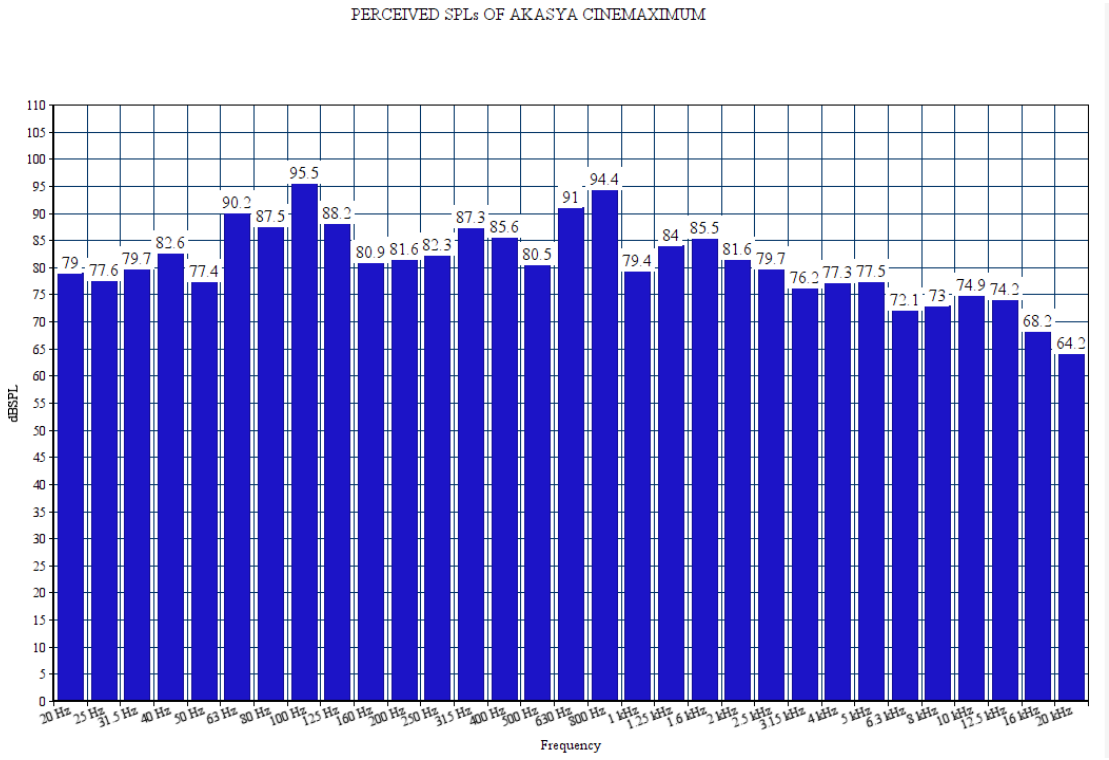

Figure 3.5 : PAA2 Frequency vs. SPL chart of Akasya Cinemas Theater 10

All results of PAA2 device are prepared as a chart. The name of the X axis indicates 'Frequency' and the name of the Y axis indicates 'dBSPL'.

Maximum level of the sound pressure level is ,,on 100 Hz, 95.5 dBSPL, minimum SPL is on 20 kHz, 64.2 dBSPL in analysis of the SPLs chart. Both devices were set to C Weighting. Decibel X Pro Sound Pressure analysis of “The Cleaning Lady” scheme is in Figure 3.6 below:

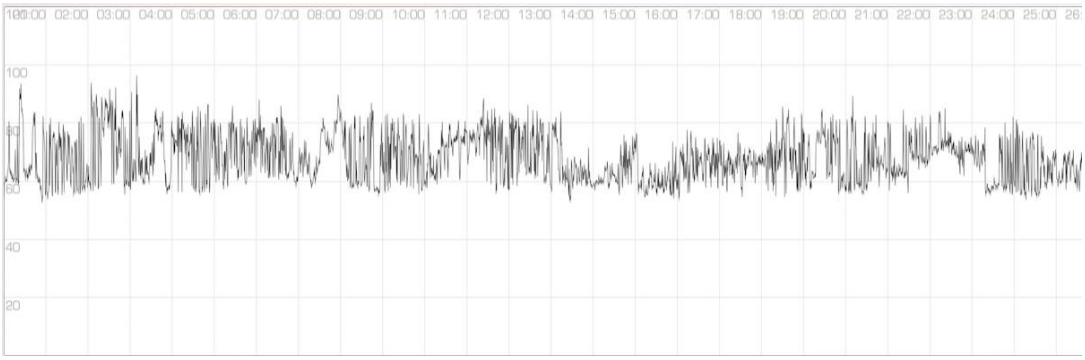

Figure 3.6 : Decibel X Pro SPL Analysis of Akasya Cinemas Theater 10.

Calibration was set to 5.1 dB with reference to PAA2 to get approximately close SPL values.The name of the X axis indicates ‘Time’ and the name of the Y axis indicates ‘dBSPL’. Decibel X Pro displays perceived minimum, maximum and average SPLs below:

Minimum: 52.7 dBC

Average: 76.6 dBC

Maximum: 96.5 dBC

Peak: 100.2 dBC

Dose (%): 4.6

TWA (dBC): 47.5

3.3 Theater #3: Emaar Cinemas

The second movie did not screen with the MPX technology in this theater so it is analyzed in theater 10, the selected seat is E-6 which is at the center of the theater. There are 2 disabled seats on A-10 and A-11. The selected seat is marked as X in Figure 3.7 below:

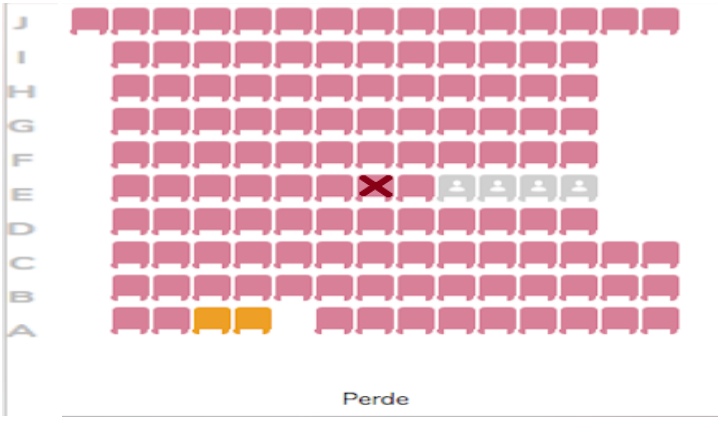

Figure 3.7 : Emaar Cinemas Theater 10 Seating plan (Url-10).

3.3.1 SPL Values and Spectrum Analysis of Theater #3

The first 25 minutes of "The Cleaning Lady" analyzed with PAA2 on Emaar Cinemas Theater 10. Results are prepared as a chart in Figure 3.8 below:

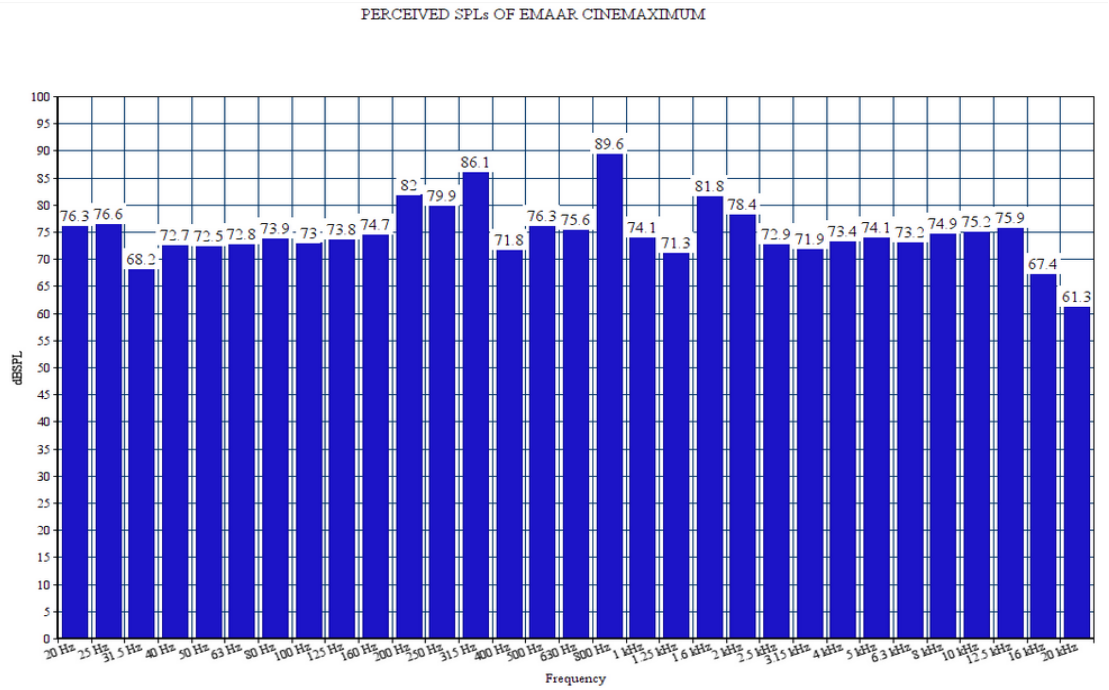

Figure 3.8 : PAA2 Frequency vs. SPL chart of Emaar Cinemas Theater 10.

All results of PAA2 device are prepared as a chart. The name of the X axis indicates 'Frequency' and the name of the Y axis indicates 'dBSPL'.

Maximum level of the sound pressure level is on 800 Hz, 89.6 dBSPL, minimum SPL is on 20 kHz, 61.3 dBSPL in analysis of the SPLs chart. Both devices were set to C Weighting.

Decibel X Pro Sound Pressure analysis of "The Cleaning Lady" scheme is in Figure 3.9 below:

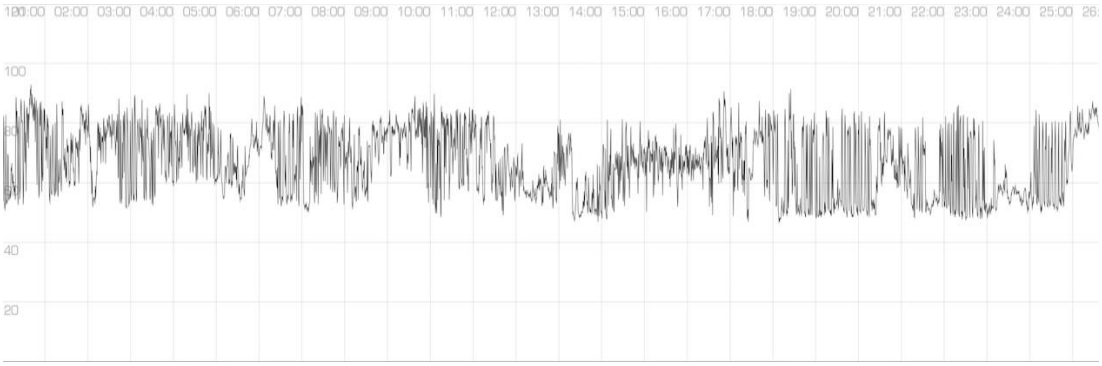

Figure 3.9 : Decibel X Pro SPL Analysis of Emaar Cinemas Theater 10.

Calibration was set to 5.1 dB with reference to PAA2 to get approximately close SPL values.The name of the X axis indicates 'Time' and the name of the Y axis indicates 'dBSPL'.

Decibel X Pro displays perceived minimum, maximum and average SPLs below:

Minimum: 46.9 dBC

Average: 77.1 dBC

Maximum: 92.9 dBC

Peak: 99.7 dBC

Dose (%): 5.1

TWA (dBC): 48.2.

3.4 Theater #4: Atlas Cinemas

Theater 1 is chosen for the second selected movie analysis and the selected seat number is 9-1. It was the same room with the first selected movie so the seating plan and the selected seat number was the same with the "The Avengers: Endgame" movie.

The selected seat is marked as X in Figure 3.10 below:

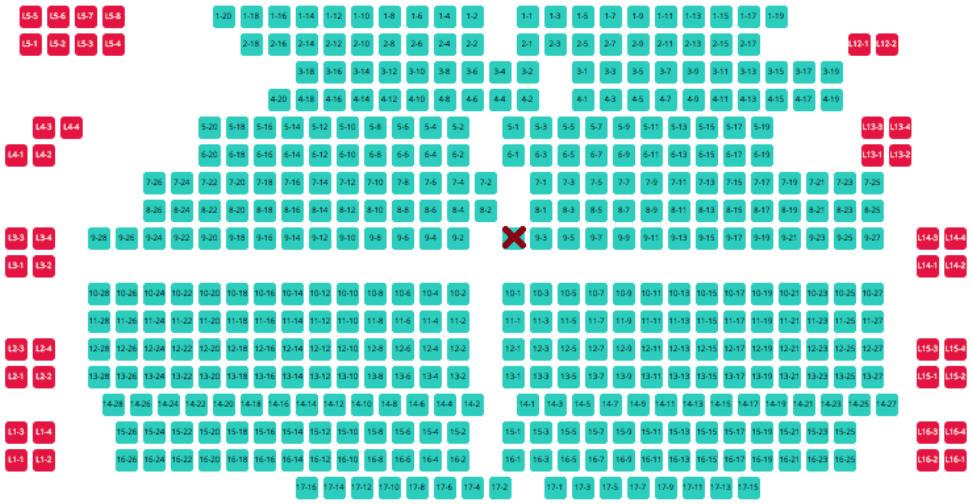

Figure 3.10 : Seating plan in Atlas Cinemas Theater 1 (Url-11).

3.4.1 SPL Values and Spectrum Analysis of Theater #4

The first 25 minutes of "The Cleaning Lady" analyzed with PAA2 on Atlas Cinemas Theater 1. Results are prepared as a chart in Figure 3.11 below:

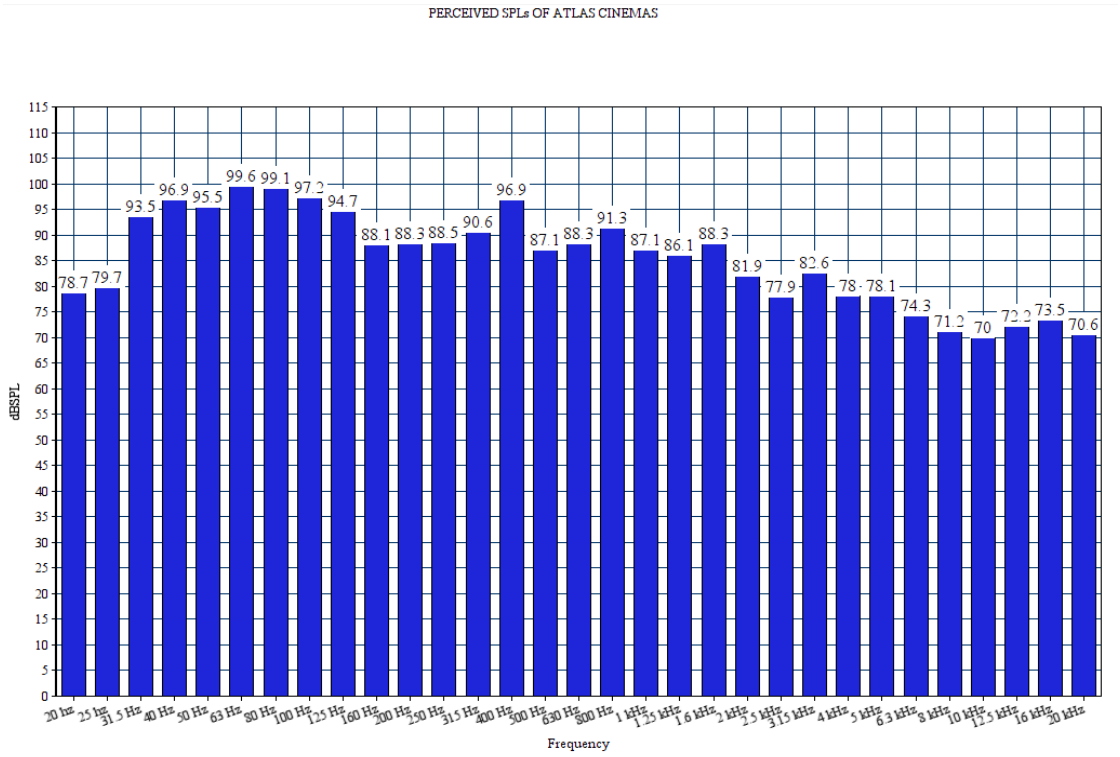

Figure 3.11 : PAA2 Frequency vs. SPL chart of Atlas Cinemas Theater 1.

All results of PAA2 device are prepared as a chart. The name of the X axis indicates ‘Frequency’ and the name of the Y axis indicates ‘dBSPL’.

Maximum level of the sound pressure level is on 63 Hz, 99.6 dBSPL, minimum SPL is on 10 kHz, 70 dBSPL in analysis of the SPLs chart. Both devices were set to C Weighting.

Decibel xPro Sound Pressure analysis of “The Cleaning Lady” scheme is in Figure 3.12 below:

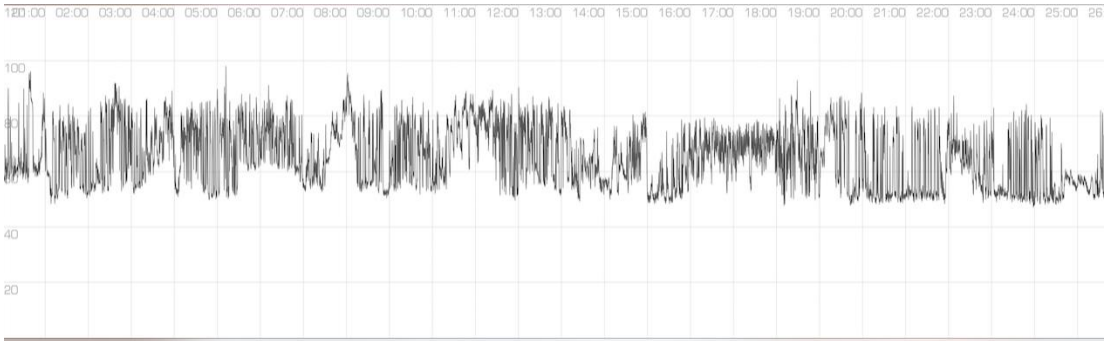

Figure 3.12 : Decibel X Pro SPL Analysis of Atlas Cinemas Theater 1.

Calibration was set to 5.1 dB with reference to PAA2 to get approximately close SPL values.The name of the X axis indicates ‘Time’ and the name of the Y axis indicates ‘dBSPL’.

Decibel X Pro displays perceived minimum, maximum and average SPLs below:

Minimum: 47.0 dBC

Average: 76.4 dBC

Maximum: 98.1 dBC

Peak: 102.9 dBC

Dose (%): 10.4

TWA (dBC): 62.7

4. RESULTS AND DISCUSSION

Acclaimed data from the analysis is compared with each other in the project. Each of the SPL results are also prepared as table.

4.1 Comparison of obtained data for the first movie

Here are the graphs for acclaimed data using Decibel X Pro application in Figure 4.1:

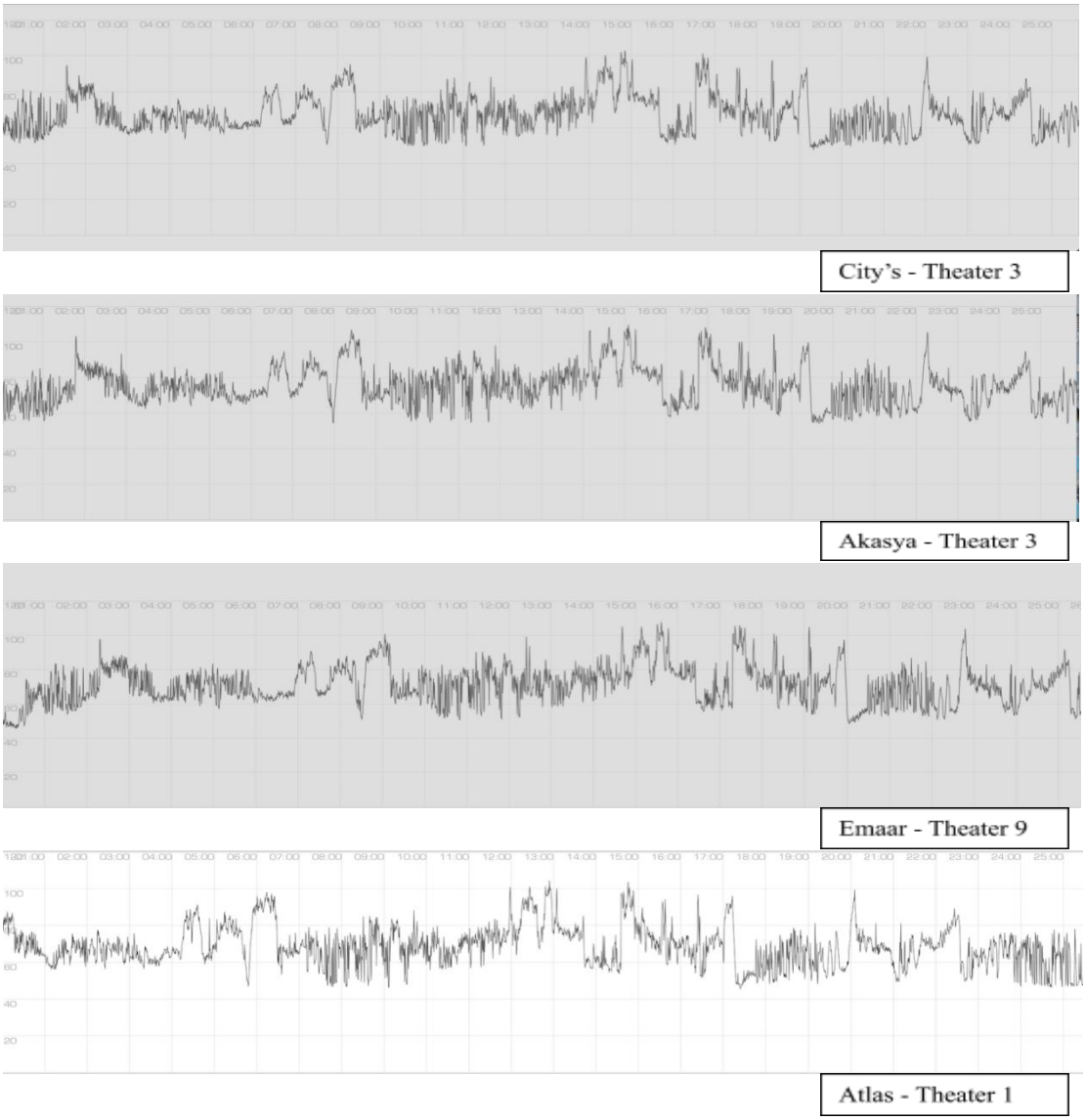

Figure 4.1 : Comparison of SPL levels in different theaters for the first movie.

The system that I created to measure these minimum, maximum and the average SPLs for each movie theater on first movie are summarized on Table 4.1.

Table 4.1 : Decibel X Pro SPL values for each movie theater on first movie.

THEATERS	MINIMUM SPL	MAXIMUM SPL	AVERAGE SPL
CITY'S Cinemas (Theater 3)	47.6 dBC	103.0 dBC	82.0 dBC
AKASYA Cinemas (Theater 3-IMAX)	51.5 dBC	109.6 dBC	89.7 dBC
EMAAR Cinemas (Theater 9-MPX)	45.6 dBC	107.7 dBC	86.5 dBC
ATLAS Cinemas (Theater 1)	45.8 dBC	104.6 dBC	83.6 dBC

As it's seen in the graphics and results that summarized with Table 4.1 on first movie analysis, Akasya Cinemas which has the IMAX technology in Theater 3 had the highest SPL value, 89.7 dBSPL (Average), City's Cinemas had the lowest SPL value, 82.0 dBSPL (Average). So the Akasya movie theater with the IMAX technology sounds quite louder compared to other movie theaters in İstanbul. There was a quite punchy response throughout the scene as you can see in Figure 4.1. On the contrary, City's had the lowest SPL in both two different movies. The average SPL value of the Atlas Cinemas was 83.6 dBSPL.

Firstly I had expected that it would show the lowest SPL value in my analysis because it was one of the oldest Cinemas in İstanbul. Considering the Emaar Cinemas, the MPX technology was a new experience for me. Even though it was not as loud as the Akasya IMAX technology, it provided quite satisfactory as sound perception to the audience. The average SPL value was 86.5 dBSPL that had the second highest SPL value after Akasya Cinemas. The system that I created to

measure first movie's maximum SPLs on sub-bass frequency range across the analyzed movie theaters on Table 4.2 below:

Table 4.2 : First movie's Max SPL values on Sub-bass Frequency range across the analyzed movie theaters (PAA2).

MAX SPLs in Theaters	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz
CITY'S Theater 3	78.7	79.7	93.5	96.9	95.5
AKASYA Theater 3 (IMAX)	80	94.5	100	103	104.8
EMAAR Theater 9 (MPX)	78	78.2	91	91.7	99.7
ATLAS Theater 1	77.2	87.1	102.3	103.1	100.1

As it's seen on Table 4.2, there was an increase on 50 Hz in Akasya and Emaar cinemas. Also, the increment on 50 Hz was more dramatic than the Akasya Cinemas. There were minor increases on each sub-bass frequency band in Emaar Cinemas. As it's seen on Table 4.2, sub-bass were loud enough and well controlled throughout the frequency spectrum in Emaar Cinemas.

In Akasya Cinemas Theater 3 (IMAX), had the loudest SPL value on the sub-bass comparing to the other cinemas. Increment throughout sub-bass frequency spectrum was much more than the Emaar cinemas. The highest SPL value on sub-bass frequency was on 50 Hz, 104.8 dBSPL.

In City's Cinemas, the SPL values on sub-bass was analyzed louder than the Emaar Cinemas. The highest SPL value on sub-bass frequency spectrum was on 40 Hz, 96.9

dBSPL and there was 1.4 dB decrease between 40 Hz and 50 Hz. In Atlas Cinemas, the SPL values on sub-bass was analyzed louder than the Emaar and City's Cinemas, lower than the Akasya Cinemas.

Even the analysis were close to the one on Akasya Cinemas, you could almost hear the slapback on low end transitions. Also, there was a decrease on 50 Hz in both Atlas and City's Cinemas. The system that I created to measure first movie's maximum SPLs on bass frequency range across the analyzed movie theaters on Table 4.3 below:

Table 4.3 : First movie's Max SPL values on Bass Frequency range across the analyzed movie theaters.

MAX SPLs in Theaters	63 Hz	80 Hz	100 Hz	125 Hz	160Hz	200 Hz	250 Hz
CITY'S Theater 3	99.6	99.1	97.2	94.7	88.1	88.3	88.5
AKASYA Theater 3 (IMAX)	108.3	105	105.1	97.7	100	96.1	93.7
EMAAR Theater 9 (MPX)	100.5	105.9	102.8	94.5	95.3	90.7	90
ATLAS Theater 1	98.8	102.4	100.7	96.5	96.4	95.1	92.1

Considering PAA2 SPL results on Table 4.3, in Emaar Cinemas Theater 9 (MPX) Theater 9, bass frequency range between 63 Hz and 100 Hz was louder than Atlas and City's Cinemas. However, the SPL levels between 125 Hz and 250 Hz were lower than the Atlas Cinemas. As it's seen on Table 4.3, there was an increase between 63 Hz and 80 Hz in Atlas and Emaar cinemas unlike the other theaters. Also, the increment on 80 Hz was dramatic than the Atlas Cinemas.

There were minor decreases on each bass frequency band in Emaar Cinemas. As it's seen on Table 4.3, bass frequency range were loud enough and well controlled throughout the frequency spectrum.

Akasya Cinemas Theater 3 (IMAX), had the loudest SPL value on the bass frequency range compared to the other cinemas. The highest SPL value on bass frequency was on 63 Hz, 108.3 dBSPL.

In City's Cinemas, the SPL values on bass frequency range was analyzed as the lowest SPL value so the perception of the bass impact was weaker compared to the other cinemas.

In Atlas Cinemas, the SPL values on bass frequency range was analyzed louder than the City's Cinemas, lower than the Akasya Cinemas. Also there was a decrease on 50 Hz in both Atlas and City's Cinemas. However, the SPL levels between 125 Hz and 250 Hz were louder than the Emaar Cinemas.

The system that I created to measure first movie's maximum Sound Pressure Levels on high frequency range (5 kHz-20 kHz) across the analyzed movie theaters on Table 4.4:

Table 4.4 : First movie's Max SPL values on High Frequency range across the analyzed movie theaters.

MAX SPLs in Theaters	5 kHz	6.3 kHz	8 kHz	10 kHz	12.5 kHz	16 kHz	20 kHz
CITY'S Theater 3	82	79.8	85.2	81.3	79.5	71.1	56.2
AKASYA Theater 3 (IMAX)	78.3	75.9	69.7	66.5	61.5	57	-
EMAAR Theater 9 (MPX)	100.5	105.9	102.8	94.5	95.3	90.7	90
ATLAS Theater 1	79.6	73.2	67.5	60.3	57.4	62.3	59.1

Considering PAA2 SPL results on Table 4.4, in Emaar Cinemas Theater 9 (MPX) Theater 9, high-ends were louder and more compressed than the other movie theaters. Unlike the other cinemas, the SPL values increased between 5 kHz and 6.3 kHz, 10 kHz and 12.5 kHz in Emaar cinemas. Also, decrease between 16 kHz to 20 kHz was minor than the other theaters. As it's seen on Table 4.4, high ends were loud enough so dialogs in the scenes sounded clear and had a well definition.

In Akasya Cinemas Theater 3 (IMAX), had the lowest SPL value on the high-ends comparing to the other cinemas and there was no data on 20 kHz band. Even though the SPL values decreased from 5 kHz to 20 kHz, high ends were well controlled. Dialogs in the scenes in these frequency bands had a good definition which is audible even on loud scenes.

In City's Cinemas, the SPL values on high ends was louder than the Akasya and Atlas Cinemas. Unlike the other cinemas, the SPL values increased between 6.3 Hz

and 8 kHz. Also, the decrease between 16 kHz and 20 kHz was more dramatic compared to the other movie theaters. In Atlas Cinemas, the SPL values on high ends was lower than the Emaar and City's Cinemas. Also the SPL values increased between 12.5 kHz and 16 kHz. Theater 1, where I analyzed, was the biggest room in Atlas Cinemas.

4.2 Comparison of obtained data for the second movie

You can see the graphs for acclaimed data using Decibel X Pro application in Figure 4.2 below:

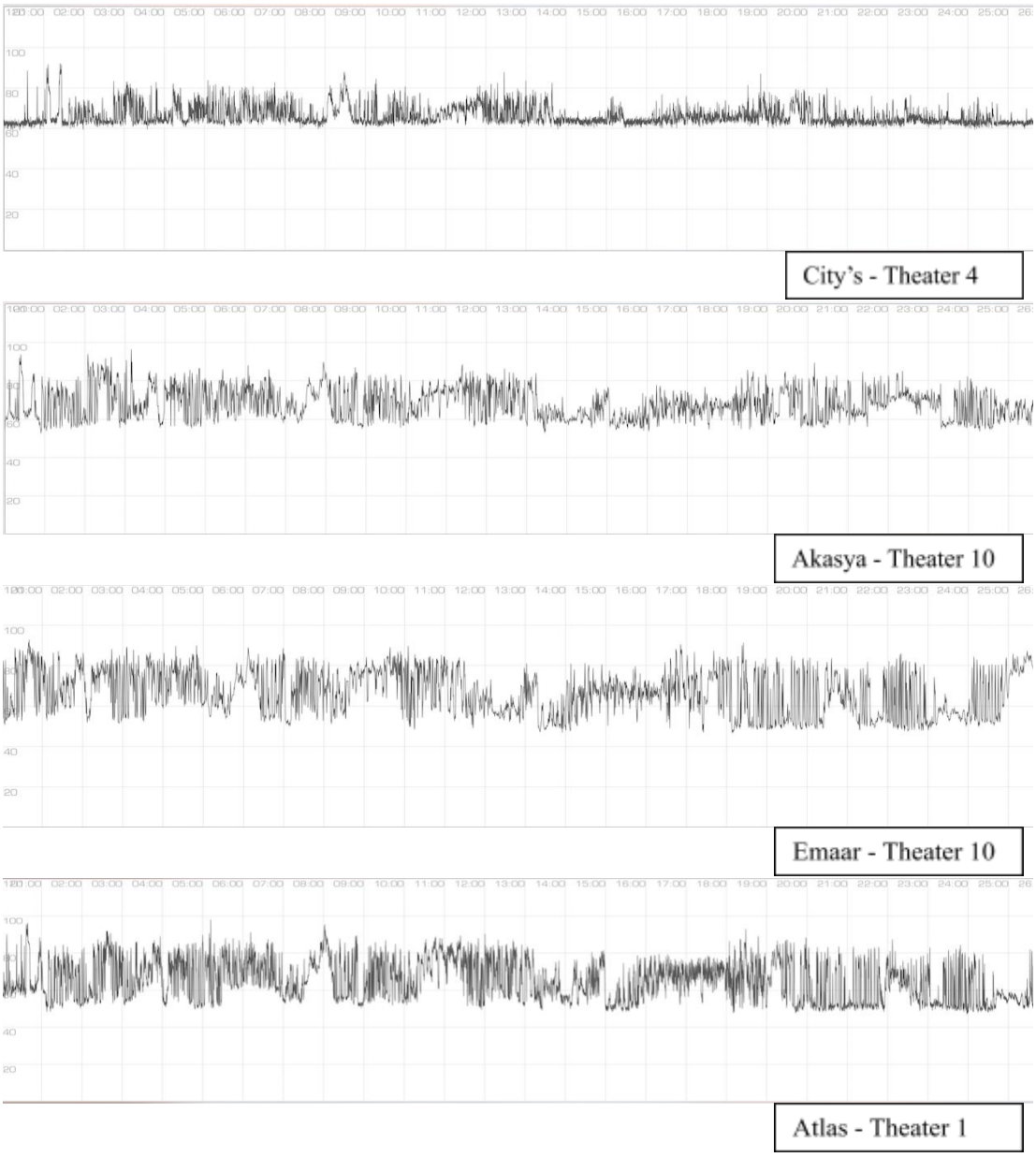

Figure 4.2 : Comparison of SPL levels in different theaters for the second movie.

The system that I created to measure these minimum, maximum and the average SPLs for each movie theater on second movie are summarized on Table 4.5.

Table 4.5: Decibel X Pro SPL values for each movie theater on second movie

THEATERS	MINIMUM SPL	MAXIMUM SPL	AVERAGE SPL
CITY'S Cinemas (Theater 4)	59.0 dBC	92.3 dBC	70.9 dBC
AKASYA Cinemas (Theater 10)	52.7 dBC	96.5 dBC	76.6 dBC
EMAAR Cinemas (Theater 10)	46.9 dBC	92.9 dBC	77.1 dBC
ATLAS Cinemas (Theater 1)	47.0 dBC	98.1 dBC	76.4 dBC

Cinemas in the graphics and the results on Table 4.5 on second movie analysis, Emaar Cinemas theater 10 had the highest SPL value, 77.1 dBSPL (Average), City's Cinemas had the lowest SPL value, 70.9 dBSPL (Average).

In this second movie's analysis, there was no room with the IMAX technology in Akasya movie theater and there was no room with the MPX technology in Emaar Cinemas. So the analysis based on ordinary rooms across movie theaters for the second movie "The Cleaning Lady".

In City's movie theater, the dynamics of the sound levels differ less than the other Cinemas so the graphical response was nearly flat except a few dynamic increases in the louder scenes on City's Cinemas (Figure 3.2). Unlike the first movie analysis, Akasya Movie theater had the second loudest SPL value. Emaar Cinemas Theater 10 sounds quite more powerful and louder compared to the other movie theaters. In Atlas Cinemas, the average SPL value was 76.4 dBSPL, in Akasya Cinemas, the

average SPL value was 76.6 dBSPL. In spite of Akasya Cinemas Theater 10 was smaller than the Atlas Cinemas Theater 1, these two of the movie theaters have nearly the same SPL values. The system that I created to measure maximum SPLs on sub-bass frequency range across the analyzed movie theaters on Table 4.6 below:

Table 4.6: Second movie's Max SPL values on Sub-bass Frequency range across the analyzed Movie Theaters

MAX SPLs in Theaters	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz
CITY'S Theater 4	-	-	-	70.6	71.2
AKASYA Theater 10	79	77.6	79.7	82.6	77.4
EMAAR Theater 10	76.3	76.6	68.2	72.7	72.5
ATLAS Theater 1	78.7	79.7	93.5	96.9	95.5

Considering PAA2 SPL results on Table 4.6, in Emaar Cinemas Theater 10, sub-bass range was louder than City's Cinemas. There was a very minor SPL value changes on the sub-bass frequency range. There was an increase on 31.5 Hz and rest of the bands only have a minor decrease on each sub-bass band as it's seen on Table 4.6. Even though average SPL value of Emaar was the loudest on Table 4.4, sub-bass frequency range was lower than the Akasya and Atlas Cinemas.

In Akasya Cinemas Theater 10, there were both increase and decrease on sub-bass unlike the Atlas cinemas. Also, there was a decrease on 50 Hz in both Akasya and Emaar Cinemas.

In City's Cinemas, there was no data until 40 Hz on sub-bass so the perceived power was the lowest than the other cinemas in the second movie analysis. In Atlas Cinemas, the SPL values on sub-bass was analyzed louder than the other cinemas.

The highest SPL value of sub-bass frequency was on 40 Hz, 96.9 dBSPL. There was a consistent increase on sub-bass throughout the scene. Like the first movie's analysis, Atlas Cinemas, because of the empty room and acoustics, sub-bass frequency range had also have a slapback effects. The system that I created to measure maximum SPLs on bass frequency range across the analyzed movie theaters on Table 4.7 below:

Table 4.7: Second movie's Max SPL values on Bass Frequency range across the analyzed Movie Theaters

MAX SPLs in Theaters	63 Hz	80 Hz	100 Hz	125 Hz	160Hz	200 Hz	250 Hz
CITY'S Theater 4	81.6	77.7	82.4	81.1	72.9	81.7	75.6
AKASYA Theater 10	90.2	87.5	95.5	88.2	80.9	81.6	82.3
EMAAR Theater 10	72.8	73.9	73	73.8	74.7	82	79.9
ATLAS Theater 1	99.6	99.1	97.2	94.7	88.1	88.3	88.5

Considering PAA2 SPL results on Table 4.7, in Emaar Cinemas Theater 10, the SPL value was the lowest compared to the other movie theaters. However, it was the higher SPL value than the City's between 160 Hz and 250 Hz so there was both a small amount of increase and decrease throughout the bass frequency range. Even though average SPL value of Emaar was the loudest on Table 4.4, bass frequency range was lower than the Akasya and Atlas Cinemas.

In Akasya Cinemas Theater 10, had the second loudest SPL value on the bass after Atlas Cinemas. There was also both increase and decrease throughout the bass frequency range.

In City's Cinemas, the SPL values on bass frequency range was analyzed as the lowest SPL value like sub-bass frequency range analysis so the perception of the bass impact was also quite weak compared to the other cinemas. In Atlas Cinemas, even the average SPL values analysis (Table 4.4) showed that it was lower SPLs than the Akasya and Emaar cinemas, the SPLs on bass frequency range was analyzed the highest. The highest SPLs on bass frequency range was on 63 Hz, 99.6 dBSPL.

Table 4.8: Second movie's Max SPL values on High Frequency range across the analyzed movie theaters

MAX SPLs in Theaters	5 kHz	6.3 kHz	8 kHz	10 kHz	12.5 kHz	16 kHz	20 kHz
CITY'S Theater 4	72	68.9	71.1	73	72.7	65.8	61.7
AKASYA Theater 10	77.5	72.1	73	74.9	74.2	68.2	64.2
EMAAR Theater 10	74.1	73.2	74.9	75.2	75.9	67.4	61.3
ATLAS Theater 1	78.1	74.3	71.2	78.2	79	73.5	70.6

Considering PAA2 SPL results on Table 4.8, 4 Theaters had increase and decrease each frequency spectrum on high ends. In Emaar Cinemas Theater 10, high-ends were louder than the City's and Akasya Cinemas, lower than the Atlas Cinemas.

In Akasya Cinemas Theater 10, had the second lowest SPL value on the high-end after City's comparing to the other cinemas. There was also a decrease after 8 Khz range.

In City's Cinemas, the SPL values on high ends was lowest compared to the other theaters, unlike the first movie analysis on Table 4.4. City's Cinemas had the lowest SPLs on each frequency spectrum (Especially on Sub-bass, bass and high-end

bands). Therefore, dialogs were significantly lower throughout the scene. In Atlas Cinemas, the SPL values on high ends was higher than the other cinemas although it had the second lowest average SPL values, as it's seen on Table 4.4.

5. CONCLUSION

This study focused on sound pressure levels and compared maximum SPLs throughout the frequency range in various movie theaters in İstanbul. It must be said that there are many other parameters which affects the sound quality such as choice of equipment which are varied in power, amplifier class and dimension, as well as in number of public address and surround (PA) speakers, acoustic isolation, resonant frequencies of the room, standing waves and occurring reflections. These factors brings out differences in different cases which should accounted and analyzed accordingly and individually.

This study also assumed that all cinemas which are analyzed are using similar technology up to a certain point which is approved and licenced by Dolby Technology. Mars Cinema Group technical administrator Mr. Mustafa Elönü rather did not want to share the information on specific types of gear and equipment they are using through the process. However, he gave information on Dolby qualified brands of cinema systems commonly used are Dolby SLS, JBL, QSC, MAG Cinema and Christie.

According to the results of my analysis, the perceived sound pressure levels have significant differences. In the first movie analysis, City's and Atlas had the lower SPLs than the other cinemas on sub-bass and bass frequency range as seen on Table 4.2 and 4.3. In City's, the low end was absorbed almost too well, that it doesn't give the punch and perceived power on these movie theater. In Akasya IMAX Theater 3, obviously the room was designed according to IMAX standards and licenced specifications. Akasya Cinemas was the highest SPLs on sub-bass and bass frequency range seen on Table 4.2 and Table 4.3 so the perceived low-end power and defined impact was quite higher than the other cinemas. Also, the average of the perceived sound levels were as expected according to the results on Table 4.1. Emaar Cinemas' SPL value was higher than the other cinemas on high ends, as it's seen on Table 4.4. The MPX technology in Emaar Cinemas made a significant difference than the other movie theaters in perceived loudness.

According to the analysis, results are compressed and/or loudness maximized. You can see the minor changes on the dynamics on SPL readings in Emaar's high frequency range analysis on Table 4.4. Overall analysis also shows a significantly equalized dynamic range through the frequency spectrum in Figure 2.11. In Atlas Movie Theater 1, SPL value of the sub-bass frequency range generally increased and the bass frequency range generally decreased throughout the scene, as it's as seen on Table 4.2 and 4.3. The low end of the Atlas Cinemas was the second highest SPL value in the first movie analysis.

Even though the results showed that it had the second highest SPLs on low ends considered to the other movie theaters, it lacked definition. The amphitheater shape and design had unpleasant effects on the overall perceived sound quality and the room caused many standing waves.

Considering PAA2 SPL results on Table 4.4, the high end of Atlas Cinemas was lower than the other movie theaters. Even the analysis showed similar results as the Akasya Cinemas, perceived loudness was different. These may cause many parameters such as the room acoustics of the theaters. Tails of the low frequencies can mask the high end bandwidth thus resulted in lack of definition.

In the second movie analysis, overall SPL results were lower than the first movie analysis because of the genre of the movie. Considering the low ends SPLs sorting of the analysis, Atlas Cinemas was the loudest, Akasya Cinemas was the second loudest, Emaar Cinemas was the third and City's Cinemas was the last according to the results on Table 4.6 and 4.7. As it's seen in the results, Akasya movie theater without IMAX technology didn't make it highest SPL values. Considering the high end's SPL values, the sorting of the analysis goes by; Atlas Cinemas was the first, Emaar Cinemas was the second, Akasya Cinemas was the third and City's Cinemas the last according to the results on Table 4.6. As it's seen in the results, City's Cinemas was the lowest SPLs on both low and high frequency ranges.

All analysis were made when there was very little or even no audience in the movie theaters. So the results of SPL values of the frequency range may well be affected by the room acoustics. It might also be different SPL readings if the theater was full.

This research proved that the movie theaters in İstanbul have significant differences in perceived sound pressure levels based on these theaters' design, size, seat capacity,

room acoustics and cinema formats. It also showed that different genres of movies (action and thriller) affect the dynamic range of percieved SPLs and how much it can differ on different movie theaters, especially on low and high frequency bands.

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APPENDICES

APPENDIX A: FEATURES OF PHONIC PAA2 REAL TIME ANALYZER

APPENDIX A: FEATURES OF PHONIC PAA2 REAL TIME ANALYZER

● Palm Size Audio Analyzer
● 31-band Real Time Spectrum Analyzer
● Built-in calibrated measurement microphone
● Sound Pressure Level Meter from 30dB~130dB
● Line signal measurement display in dBu, dBV, or Voltage
● A, C weighting or flat
● 3 level range selection for dB SPL and line signal
● Line signal measuring range: dBu = -50 ~ +40dBu dBV= -52 ~ +38dBV Volts = 5mV ~ +80V
● Maximum level display
● 4 standard response times: 35ms, 125ms (F), 250ms (M), 1sec (S)
● 10 memories for measurement and 6 for average calculation
● 160 x 160 graphic display with back light and contrast adjustment
● Phase checker
● SPL meter Calibration through sound level calibrator (eg: B & K Type 4231)
(Adapter power supply operation available. When power is used from adapter, it automatically cuts off battery power)

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