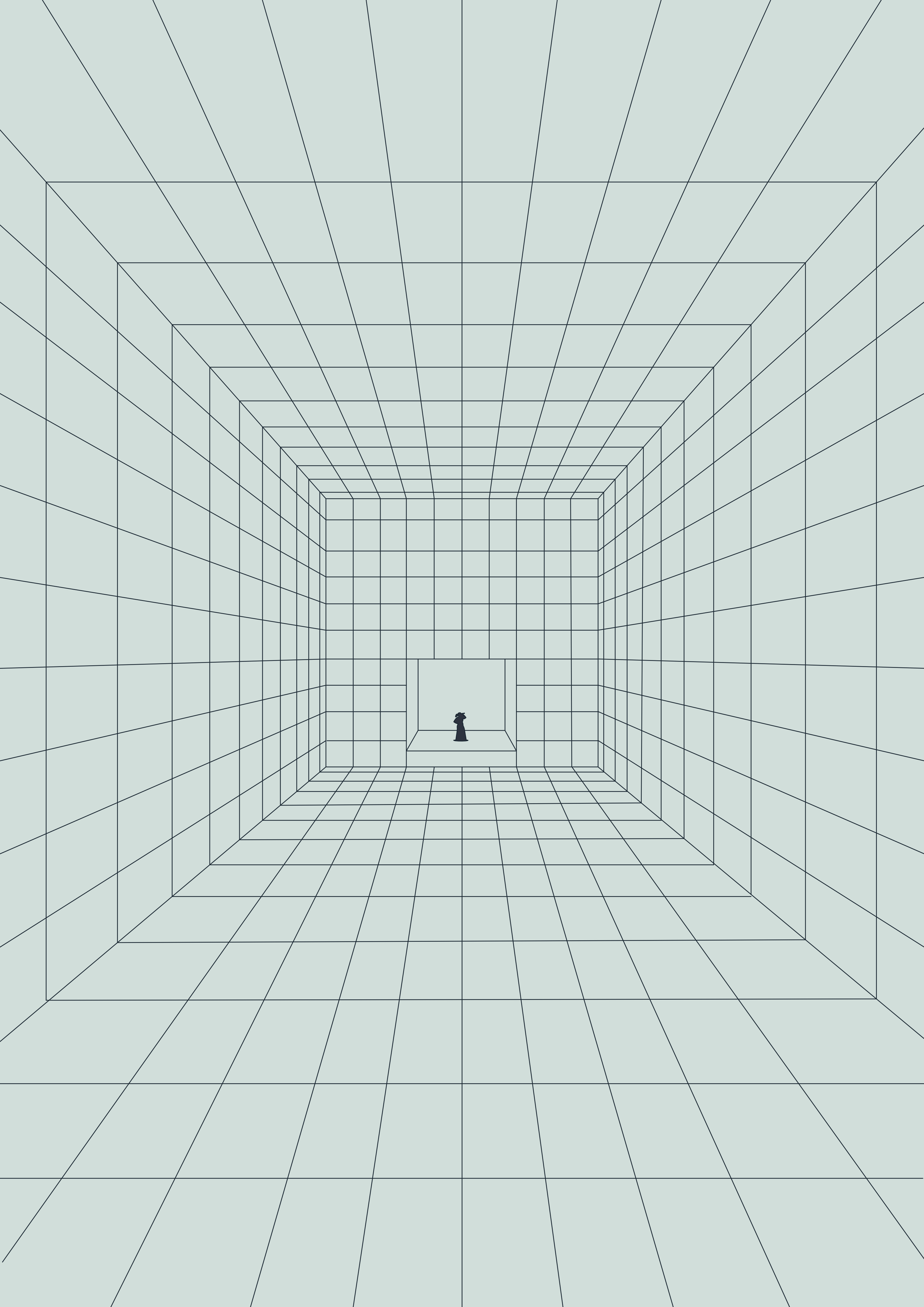

VERSATILE VENUE: HOW CAN THE ACOUSTICS OF A SPACE BE OPTIMIZED FOR VARIED PERFORMANCES?

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INTRODUCTION

What are the ideal parameters for designing a concert hall, and how can these be integrated into a versatile venue? This is the main goal this research report aims to solve. Case studies, literature, and simulation help to form a clear thought for design, and venue that can accommodate and maximize acoustical performance of the space. When designing and constructing a performance space there are a wide variety of factors that influence the overall design of the venue. Shape, volume, materials, location, all contribute to the acoustics of space. Each aspect must synchronize with the others to achieve desired acoustics.

Measures of Acoustic Performance

Aside from just sound, acoustics are comprised of many other factors. Each hall has different performance requirements for the space, so acoustician's measure sound to create the ideal performance venue.

Early Decay Time (EDT, also early reverberation time)
This is the time that it will take for a sound to decay 10 decibels after being stopped. This is then multiplied by a factor of 6 which allows comparison of EDT and RT. EDT is an indicator of acoustical quality, because instruments are typically playing notes a in rapid consecutive order, which does not always allow for reverberation time to be heard, dependent on the type of performance taking place.

Reverberation Time
One of the more flexible variables is reverberation time (RT). This is the number of seconds it takes for a sound to decay 60 decibels after being stopped, or the time it takes for a sound in a hall to become inaudible after the sound is stopped. Halls that have been deemed acoustically superior typically have a RT of 1.8 to 2.0 seconds when fully occupied. The RT of a hall also changes with an audience as the sound is absorbed and reflected off them. RT is not a fixed goal; it is a tool that can be used to enhance the sound of a space whatever way is seen fit. However, if the time is off or doesn't compliment the performance it can become easily noticeable to the listener and make their experience less enjoyable. RT is only experienced in indoor venues; in outdoor environments sound will continues to travel outward becoming weaker. When a single note is played on the stage of a concert hall it radiates in all directions reflecting off the surfaces that enclose the space.

A listener hears the first direct sound wave, followed by a series of reflection waves. A listener will experience various waves of sound when listening to a performance. The first one being the direct sound. This is the sound that travels directly to the listener from an instrument or soloist. This is followed by the early sound wave, which is a combination of all the direct and reverberant sound a listener hears in the first 80 milliseconds. This is followed by the reverberant sound which encompassed all the reflections heard after the first 80 milliseconds. In one second these reflections can occur around 20 times. The sounds continue reflecting off the surfaces until it gradually reaches inaudibility. Longer reverberation times result in what is called a 'live' hall. Liveness is a broad term that refers to frequencies that fall between 350 and 1400 Hz.

Definition or Clarity(C80)
"Name the degree to which a listener can distinguish sounds in musical performance." (pg. 24, Beranek, 2004) Definition takes 2 different forms, horizontal definition which is related to tones played in succession, and vertical definition, this is related to notes that are played simultaneously together. Horizontal Definition "refers to the degree to which sounds that follow one another stand apart." (pg. 25, Beranek, 2004) A musical composer can manipulate factors that determine the horizontal definition. Vertical Definition "refers to the degree to which notes that sound simultaneously is heard separately." (pg. 26, Beranek, 2004) Vertical definition can also be manipulated by the composer. To play a musical piece correctly the composer must conduct the ensemble in a way that achieves the degree of definition that the composer intended it to be played with. It is good to have C80 of zero to n -2.0 dB, however seats in the back of the auditorium will have lower levels, while seats closer to the stage will have higher levels.

While there are many other factors that comprise good acoustics, these ones will be the focus of the simulation phase. They provide strong point of comparison and are generally a good way to determine how a hall will sound. RT/EDT, and clarity/definition both correlate with one another.

The initial time delay gap (ITDG)
This refers to the amount of time it takes for the first reflections to reach the listener after hearing the direct sound. Having a shorter ITDG creates acoustical intimacy within a space. A good hall in the middle of the floor has and ITDG of 25 msec or lower, fair halls exceed 35 msec, and poor design can exceed 60 msec which is more than double the ideal time. To achieve a low ITDG a hall should be narrow and have walls that are parallel to one another. In a fan shaped hall or others that do not have the best design for acoustics reflecting panels can be incorporated to reduce the ITDG below 25 msec.

Resonance
This is when an object vibrates at a maximum amplitude in response to an external force or vibration. It can occur in concert halls when sound waves reflect off the surfaces and interfere with one another. A good example would be an opera singer shattering a wine glass as their voice is able to align with the frequency in which the glass is vibrating causing it to shatter.

Spaciousness
This phenomenon comes primary from lateral reflections within the hall. The reflections make it seem like the sound is coming from a larger width than the actual instrument producing the sound. This is a main factor in determining whether one hall sounds better than the other. This is achieved when lateral reflections enter the two ears separately with the correct degrees of difference. This makes the listeners classify the hall as having superior acoustics. Less spaciousness will result in the hall having poor acoustical quality that is discernible from other halls.

Texture
This refers to the subjective perception of a sound by a listener in relation to how the early sound reflections arrive at their ears. In an ideal hall you want the reflections that follow the direct sound to arrive a uniform sequence. If there are notable pauses and inconsistent gaps within the arrival, it will offset the sound and diminish the acoustical integrity.

Echoes
These are delayed reflections that are loud enough to disrupt musicians while performing, and the listeners in a hall. Echoes are more prominent in halls that have high ceilings and tend to affect halls with shorter reverberation times more.

Dynamic range
This refers to the range between the softest and loudest sounds that can be accurately reproduced in an environment. A wide dynamic range enables the capture of both quiet and loud sounds, enhancing depth and realism in live performances. Background noises need to be minimized or eliminated to allow for a dynamic range, and superior acoustics in general.

DESIGN CONSIDERATIONS

In addition to acoustical measurements there are many other components that affect how a hall sounds. Design and material choices create good acoustics in a hall and allow one to reach desired measurements.

Hall Shape
Many top-rated concert halls tend to be designed in a traditional shoe-box shape. This is due to the parallel walls that provide strong reflection in the hall. However, in more recent designs it is becoming apparent that the space can be customized to fit the desired acoustic goal. Fan, round and ellipse shaped halls tend to have less impressive acoustics and often require more modification to achieve a sound that is enjoyable for attentive listeners.

Balconies
Balconies are used to decrease the distance between the stage and the listener. Balconies with minimal overhang are preferred as ones with deep angular designs. When the overhang is too deep it muffles the sound quality for the listeners in the back rows. Minimizing the overhang and slope of the seating can lead to a successful design of balconies.

Audience Considerations
Smaller audiences can provide better acoustics. If the audience is too large it can be hard to accommodate the way they impact the hall. Chairs can absorb more when the audience is divided into several small sections as opposed to larger blocks of chairs. Chairs should be comfortable and spaced close together to lower cost and not compromise sound integrity.

Stage Design

Balance, blend, and ensemble are all attributes that rely on the design of the sending end of the hall. This refers to the walls and ceiling behind the stage. When designing the shape of a stage there are major disadvantages to ones that are too wide or too deep. When a stage is too wide it can cause a listener to hear instruments on one side before the other. This can disrupt the balance and blend of an orchestra or symphony. Similarly, if the stage is too deep it can cause the listener to hear the instruments at the back of the stage noticeably late, which also disrupts the acoustical performance and quality to the listener.

A stage can be modified with risers and sound panels to enhance and accommodate a wider variety of performances. Reflecting surfaces can also be added to the edges of the stage to enhance the communication between a conductor and orchestra. The stage design must incorporate reflecting surfaces and diffusing irregularities into the design of the sending end of the hall. The stage must also compliment the overall shape of the hall maximizes sound projection to the entire audience.

Material Affects

Warmth in acoustics is determined by how clearly the bass is heard throughout the hall. Material choices affect this factor the most. If there is too much upholstery on the seats or draping it can absorb too many high frequencies causing the bass to become overly prominent. On the contrary, using to many smooth surfaces in hall, wood panels for example, will result in too much bass being absorbed as these materials tend to absorb low frequency sound.

Acoustical Glare can occur when sounds waves reflect off too many smooth surfaces and can take on harsh brittle quality. To prevent this many halls, have irregularities or ornamentation along the walls to help prevent this problem from happening.

Brilliance is created from having prominent treble frequencies in sounds that decay slowly over time. These frequencies can be affected if the hall has to many sound-absorbent materials, so it is best to find a strong balance when designing.

PERFORMANCE FACTORS

There are a variety of ways in which musicians can control the acoustics of a space. You could design the most acoustically impressive hall, but the performers must deliver a strong performance that is balanced for the design to be appreciated.

Balance is a variable that is typically controlled by the performers and conductors. It refers to how different sections of an orchestra or vocalist interact with each other. The main design take away is to make sure that the stage design does not amplify one side over the other when performing.

Blend is the mixing of instruments from the orchestra and how the sound together. The reflecting surfaces around the stage affect blend the most and need to be designed to help the performers sounds more harmonious.

Ensemble is the performers' ability to play in harmony and unison, so they complement one another contributing to the acoustic sound. Reflectors around a stage should carry the sounds from one side to the other allowing performer to better hear one another. Risers are also used frequently to allow performer to better see each other on the stage, this also helps them maintain uniformity and ensemble when performing.

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METHODOLOGY

Data Collection

This will be the first step in guiding my research. Using literature and case studies to inform test models.

Acoustic Research
I will be gathering information related to acoustic design within a space. Aspects such as reverberation time, diffusion, sound distribution, and sound isolation will provide background in acoustics. Additionally, I will review ideal shapes, sizes, materials, locations, and sound absorption techniques. This will create a baseline of knowledge and information that will be used to inform my research, and design program for this project. Acoustic data that impacts the performance will also be of focus. Aspects such as reverberation time, sound isolation, diffusion, and sound distribution data will provide context to help inform my research. This as well as most of my data will be sourced from literature and software programs.

Case Studies
I will be completing 6 case studies and comparisons on a range of concert halls to inform my trial designs. This will allow me to look at what has worked well in the past and what can be improved upon moving forward, and I plan to make this a major focus when researching. Case studies will also provide information on what locations work best; what materials are commonly used when designing music venues.

Analysis

Conceptualization
During this stage I will be taking all the information from the previous 3 steps and determining what the best conditions are for a music venue. I will select ideal materials, and traditional hall shapes for my project, and create a baseline guide for my final design. This will then lead me to design a variety of concert hall layouts that fit each different kind of performance. I used Rhino 7 for the design of these spaces and base the configurations of the case studies and research that I have gathered.

Odeon Simulation
At this step I will use the Rhino models and place them in Odeon for acoustic testing. From this I will be able to make note of what I need to determine the best layout for a versatile venue, and what problems may arise in the design phase next semester, this will allow me to conclude my research and add to my design program.

LITERATURE REVIEW

Throughout this research process, literature has become a fundamental component in the project. Many sources were used and have all been listed in the end of the document. These three have been some of the more commonly used sources and have each contributed to this project immensely.

Concert And Opera Halls – Leo Beranek
Concert and Opera Halls provides a collection of 66 auditoriums from across the world. It is essentially a compilation of brief case studies with key information all in one place. In addition to these case studies there are chapters that cover other considerations when designing for acoustic performance. This source ranks the halls subjectively, and not just based on acoustics. The rankings were only done by music conductors, critics, and other professionals who work in the spaces frequently. Each hall was then placed in one of six categories ranging from A+ “Superior” to C “Fair.” So, while the ranks are not scientifically based, they are from experts in the field who know what a good acoustics sound like. From this source expert opinions on different designs have been noted, which will helped develop conceptual designs for simulation. The rankings also provide context on the best shapes, sizes, and layouts that work well for mostly musical performances.

There is a need to be mindful of the subjective nature of the document. Due to this, sources were cross referenced to confirm the statements within the source to verify credibility. Many of the concert halls within the same category tend to have similar design trends, shapes, and materials, which is worth noting and can be concluded that there are certain shapes that make a more ideal environment as far as musical performances are concerned. The author himself is a well-respected acoustician who has published several books on the topic, solidifying himself as a more influential individual in the world of acoustics.

Architectural Acoustics – Christopher J. Brooks

This book provides information on how acoustics work and how to achieve high quality acoustic sound in a space. It walks you through step by step and explains the reasons behind acoustic design. This source provides a solid foundation of acoustical information. It is factual and unbiased and has straight forward explanations and examples. Its content is valuable and covers a large portion of my research. The Author makes a point to write in a comprehensive way that makes acoustics easy to understand.

It can be referenced for a variety of topics within acoustic design and has been used frequently through this process. I don’t want to limit myself to just this, I want to make sure I’m doing research into similar topics to ensure what is presented is factual, and it will be a good source for inspiring ways to expand my research. It is just about acoustics which is not the only component that I will be researching. I will need to combine the information that I take from this source with others to accomplish my research aim.

Acoustics of Multi-Use Performing Arts Centers – Mark Holden

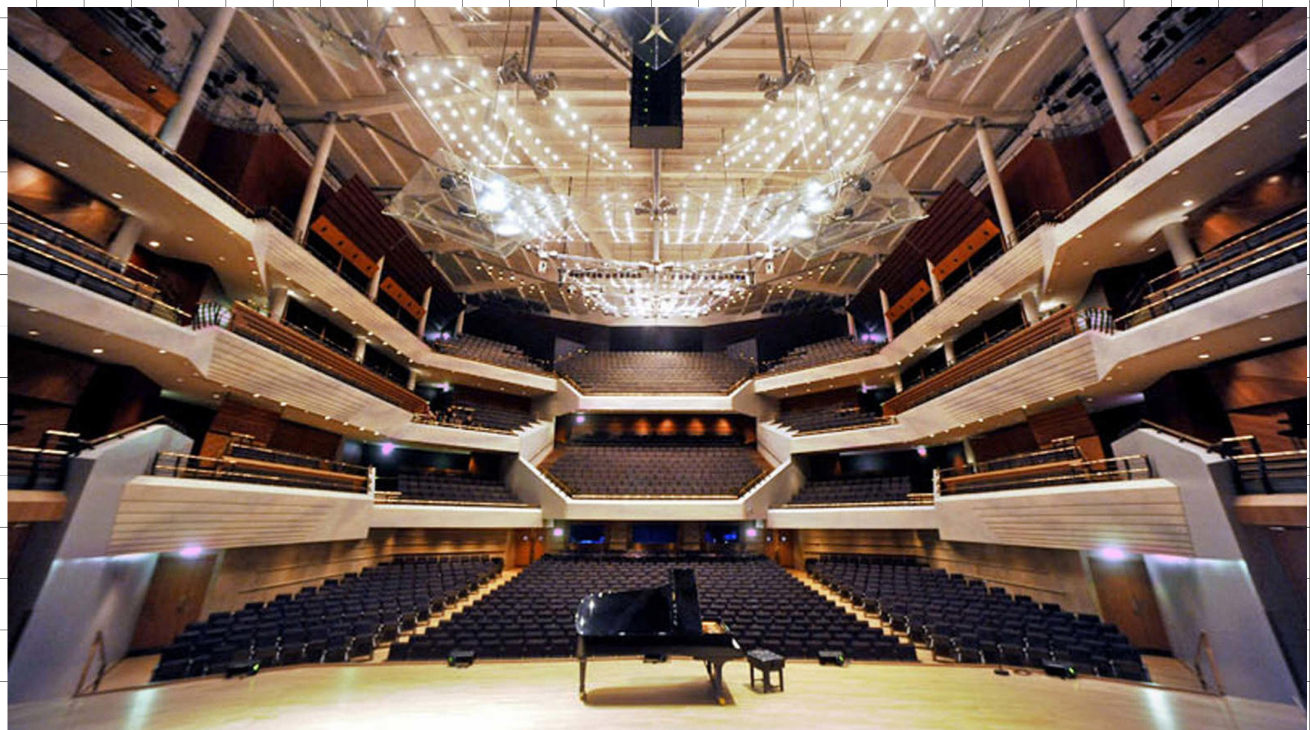
This book covers many design facets involved with multi-use performing centers. Throughout the research process it has been used to increase my understanding of acoustics, as it is written with a strong focus on design, as opposed to from just the perspective of an acoustician. Additionally, it walks the user throughout the design process of a hall and how good acoustics can be achieve. Insight is provided on what specific architectural considerations that affect acoustics and how to combat potential problems.

Unlike some other sources, Holden incorporates “Myths” about the acoustic design field at the end of each chapter. These were extremely useful as he addresses many common questions and concerns that designers have. This source is also more recent than some of the other ones used and covers topics such as “Electronic Architecture Systems” in-depth which is not covered as well in some other sources. As this source is from such a strong design perspective it does lack some acoustic terminology and variables that the other sources covered, however it still has provided a wealth of knowledge throughout this process.

CASE STUDIES

BRIDGEWATER HALL

MANCHESTER, UNITED KINGDOM



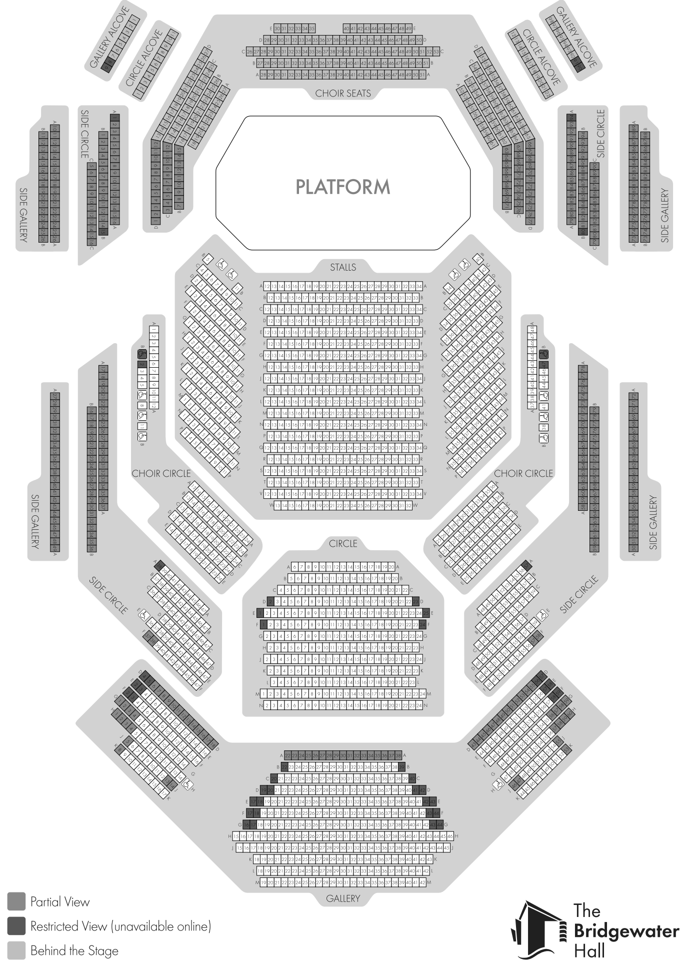
Bridgewater Hall is well known venue located in Manchester, UK. Over the years it has gained recognition for it acoustic qualities. Most frequently hosting concerts, opera, and symphony. The hall is designed in a shoe box like shape, which is considered optimal for acoustic performance. This shape allows for a well-balanced distribution of sound throughout the entire space, ensuring that all audience members receive a consistent listening experience.

The walls, ceiling, and other surfaces are constructed with materials that have appropriate diffusion and absorption properties. This results in a pleasant and enveloping reverberation that adds warmth and resonance to the sound, particularly suited for orchestral and choral performances.

The seating layout is designed to create an intimate and immersive experience for the audience members. The seating is tiered, ensuring clean sightliness to the stage and optimizing the sound. Additionally, the seats are upholstered with materials that provide appropriate absorption characteristics, reducing the chances of sound reflections from the audience.

The walls, ceilings, and balcony fronts are angled and shaped to provide optimum sound reflection and diffusion. These design elements ensure that sound waves from the stage are directed towards the audience in a controlled manner, avoiding excess reflection.

The Hall incorporates various acoustic treatments to achieve optimal sound quality. These treatments include strategically placed diffusers, absorbers, and reflectors to control the sound distribution, eliminate echoes, and minimize any unwanted resonances.



Architect: Renton Howard Wood Levin
Consultants: Arup Acoustics
Construction completion: 1996
Project Cost: 42 million euros
Seating Capacity: 2357
Auditorium Style: Rectangular Vineyard
EDT: 2.40

Materials
Ceiling: Pre cast, sound-scattering concrete panels
Side Walls: Inner wall plaster, balcony fronts, and reflectors, 1.2 inch glass reinforced gyp-sum
Floors: Oak wood embedded in concrete
Suspend canopy: Made of curved glass panels, over the stage and choir, some have adjustable heights
Stage Floor: Tongue-and-groove boards over airspace grille
Seats: Wooden, on metal frames, with perfo-rated upholstery on the seat and backrest

ROYAL ALBERT HALL

LONDON, UNITED KINGDOM

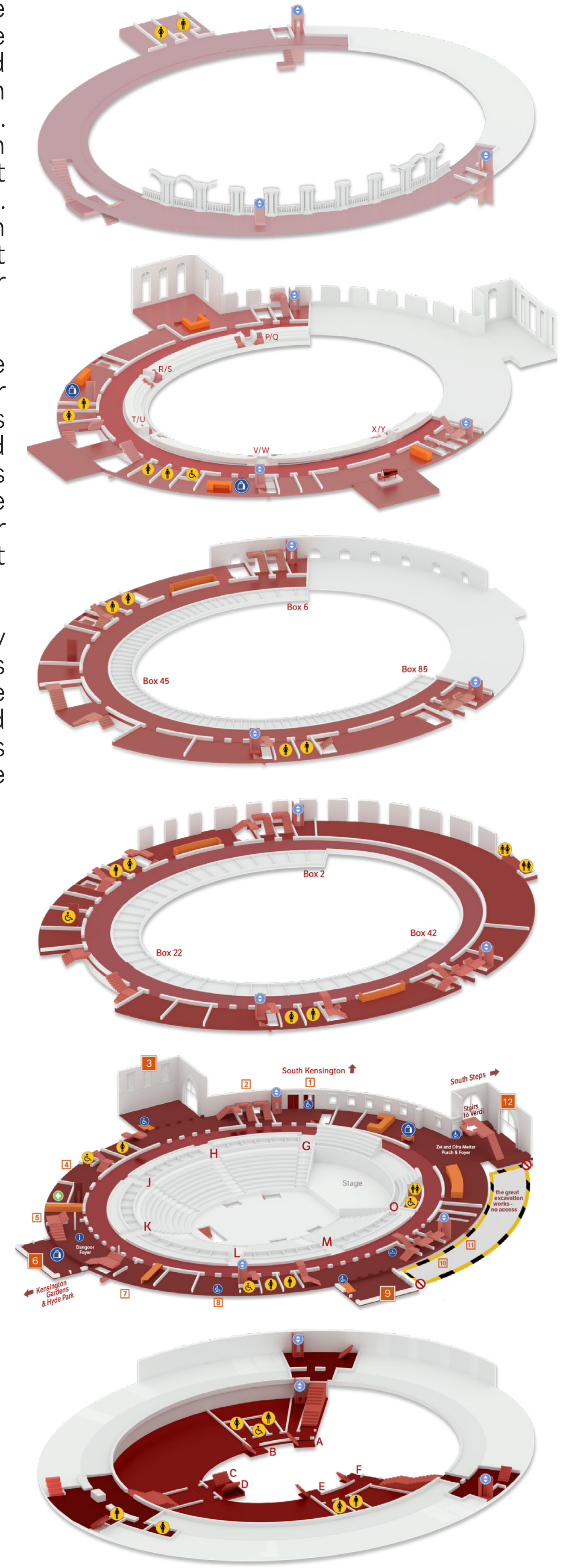
Royal Albert hall is well known around the world for its size and acoustics. Over the years the halls acoustics have improved to a more impressive level creating an enjoyable experience for the listeners. The initial design had to be modified with the addition of circular sound absorbent disks that helped improve the acoustics. In addition to these disks the hall has an extended stage and domed roof that help extenuate the elliptical shape, further enhancing the acoustics of the space.

The hall has a capacity of over 5000 people which is much larger than most other concert halls studied. The design takes inspiration from classical architecture, and ancient amphitheaters to mimic buildings from the past. The elliptical nature of the hall allows for the audience to have clear sight lines as they are a critical component of acoustics.

The hall is accompanied with a rich history that dates back to the 1800's. It was originally designed as a tribute to Prince Albert by Queen Victoria. It was designed as a collaboration between Capitan Francis Fowke, and Lieutenant Henry Scott of the Royal Engineers.

Architects: Francis Fowke, Lt. Henry Scott
Construction completion: 1871
Project Cost: 200,000 euros
Seating Capacity: 5,222
Auditorium Style: Vineyard
EDT: 1.42 sec

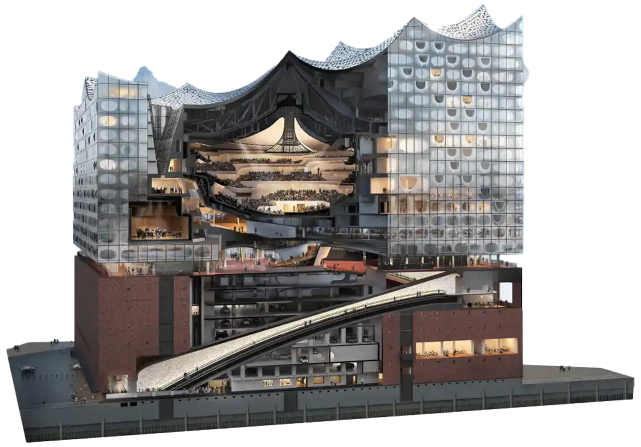
Materials
Ceiling: Plaster Finish
Walls: Plaster, and Thin Wood
Auditorium floor: Wood and Concrete
Stage Floor: Thick wood over airspace
Seats: Upholstered



ELBPHILHARMONIE

HAMBURG, GERMANY

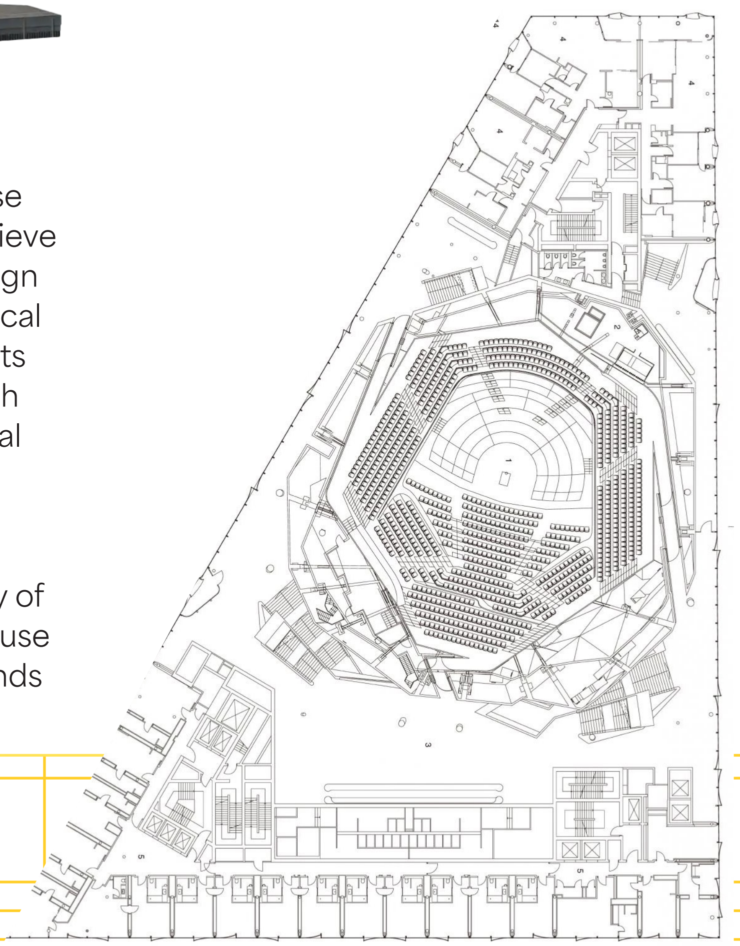
The Hall sits on top of the old Archaic Kaispeicher. Originally was constructed between 1963 and 1966, and was used as a warehouse prior to the complex being added on top of the structure. The old warehouse provided a structural base to build the philharmonic with the edition now marries the original shape of the warehouse. The top of the structure is comprised of a curved glass facade which created a new visible landmark that has added something new to the traditional horizontal layout of the Hamburg cityscape.

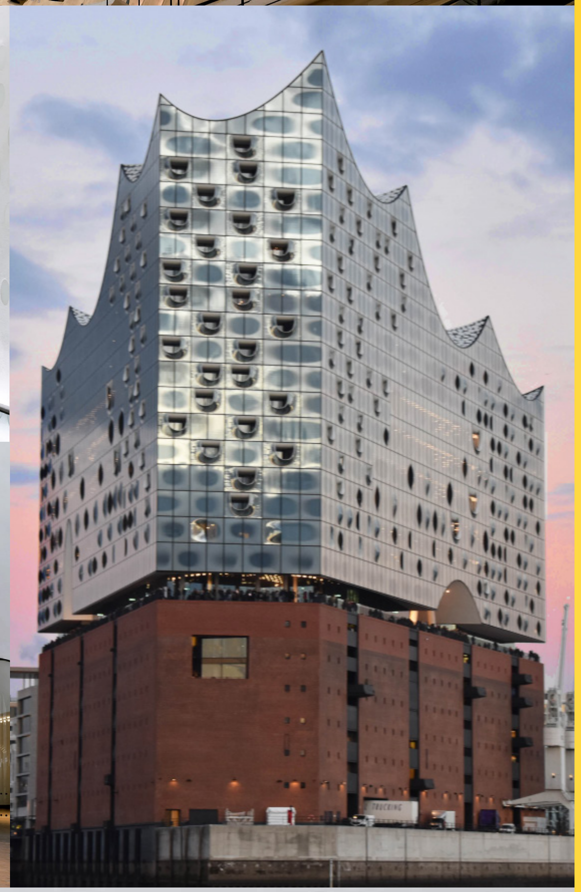


When designing the concert hall an emphasis was put on making sure the audience did not feel distant and is close to the stage as possible. In order to achieve this goal, they began by basing the design on a vineyard shape. To achieve acoustical intimacy the designers place all the seats in small clusters that were surround with sound reflecting walls for each individual group of seats. There is also a strategic placement of reflectors around the hall to ensure that sound is being projected evenly throughout the space. A majority of the design was accomplished with the use of digital modeling to optimize the sounds quality of the hall.

Architect: Herzog & de Meuron
Consultants: Nagata Acoustics
Construction completion: 2016
Project Cost: 800 million euros
Seating Capacity: 2100
Auditorium Style: Vineyard
EDT:2.3

Materials
Ceiling: HGF, milled MS
Walls: HGF, milled MS
Auditorium floor: Wood Flooring on HGF
Stage Floor: Oregon pine 50mm supported with wooden joists and sleepers
Canopy: HGF, milled MS
Seats: Upholstered
HGF: High-density gypsum fiberboard





CONCERTGEBOUW

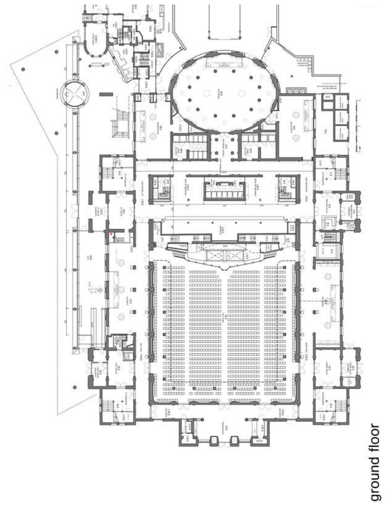
AMSTERDAM, NETHERLANDS

MUSIKVEREIN

VIENNA, AUSTRIA

BOSTON SYMPHONY HALL

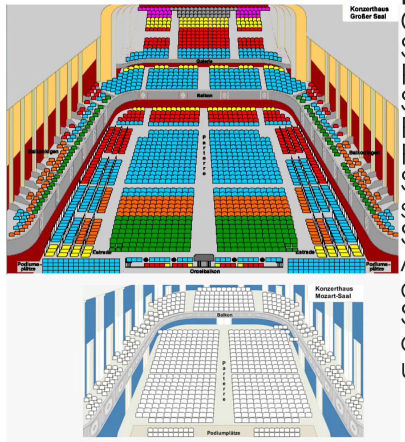
BOSTON, UNITED STATES



Materials
Ceiling: 1 1/2 inch plaster on reeds, coffered ornamentation
Side walls: Below Balcony plaster on brick, above balcony plaster on reeds
Rear Walls: Below Balcony plaster on brick, above balcony plaster on reeds
Floors: 5 inch concrete on top of hardwood boards
Stage Floor: Heavy wood over deep airspace
Stage Height: 59 inches
Added Absorption: 700 sq ft of drapes
Seating: Upholstered in thick hard weave material

Architect: A. L. van Gendt
Construction completion: 1888
Seating Capacity: 2037
Auditorium Style: Shoe box
EDT: 2.63
Clarity:

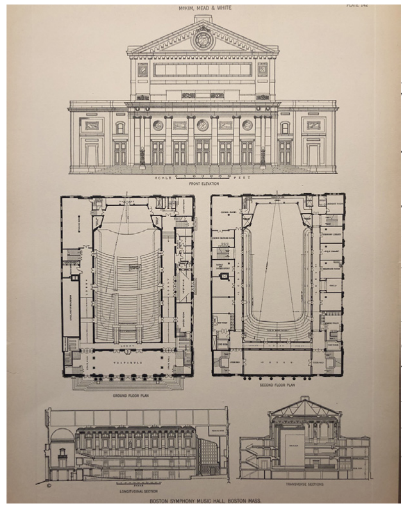
All three of the concert halls are similar. Each one is a traditional shoe box shape, has similar materials for each component of the hall, and were built in roughly the same time period. The dimensions are similar but not the same. These three halls are all ranked as the best concert halls in the world, the big three if you will.



Materials
Ceiling: Plaster on spruce wood
Side walls: Plaster on Brick
Rear Walls: Plaster on Brick
Stage Walls: wood
Balcony fronts: Plaster on wood
Floors: Wood, no carpeting
Stage Floor: Wood risers over wood stage
Stage height: 39 inches
Added Absorption: 200 sq ft of drapes
Seating: Wood base with 4ich of cushion covered by porous upholstery, rear seats are plywood

Architect: Theophil Ritter von Hassen
Construction completion: 1870
Seating Capacity: 1680
Auditorium Style: Shoe box
EDT:3.04
Clarity:

Since all of these halls are so successful and highly ranked, I used them to base my initial prototypes off of. Sticking to their traditional shoe box shape, I mimic my designs after them. Each hall has also stood the test of time and proven that as a building ages it does not lose its acoustic ability.



Materials
Ceiling: 0.75 inch plaster on a metal screen
Walls: 30% Plaster on metal lath, 50% plaster on masonry backing, 20% 0.5 - 1 inch wood paneling
Floors: Flat concrete with parquet wood affixed
Carpets: Thin on main aisles
Stage enclosure: Wood paneling ranging from 1/2 - 1 inch thick
Stage Floor: 1 1/2 inch wooden planks over a large airspace with 3/4 inch of flooring on top
Stage Height: 54 inch
Seating: the armrests and cushions are made of leather over hair, with the under seats and arms solid wood

Architect: McKim, Reed, and White
Consultants: Wallace C. Sabine
Construction completion: 1900
Seating Capacity: 2625
Auditorium Style: Shoe box
EDT:2.37
Clarity:

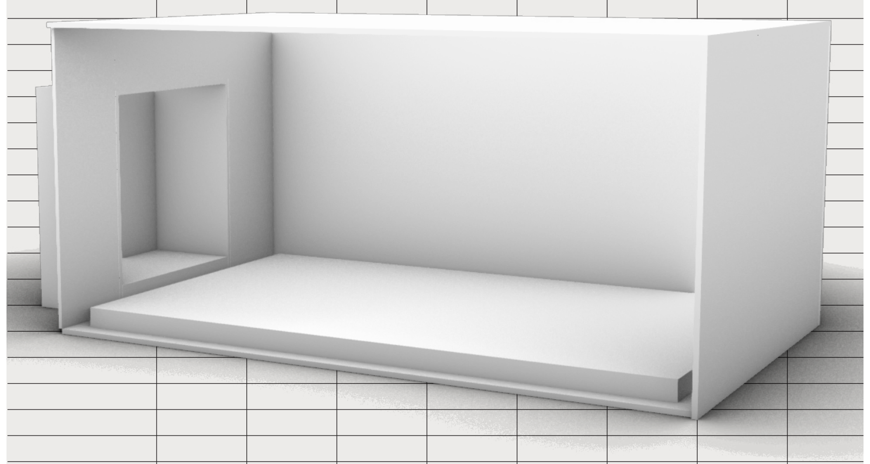
PROTOTYPES

To begin the simulation process 6 3D models were rendered in Rhino. Rhino 7 software is a computer aided design and modeling software that allows you to create complex 3D models and designs. It can support a wide range of tools that enable users to create architectural structures that are then able to be exported in a variety of formats. The models were influenced by the 3 best concert halls Boston Symphony Hall, Concertgebouw, and Musikverein. A shoebox shape was utilized for halls 1-3, and a trapezoid shape for halls 4-6. Each hall has a stage that is 40ft wide, 20 ft in depth, 5ft off the ground. The stage enclosure has a height of 35ft above the stage.
Each hall was then exported as a DXF to Odeon Auditorium. This software is extremely good at assessing auditorium and concert designs. It provides advanced acoustic modeling and simulation capabilities for these designs and is capable of accurately predicting and simulating the behavior of sound waves within a space. This allows architects, acousticians, engineers, and any other interested parties, to optimize sound quality and clarity of an auditoriums.

Why Odeon?
Odeon can accurately model the absorption, reflection, and diffusion of sound within an auditorium space. This helps in determining the optimal placement of acoustic treatments like panels, diffusers, and absorbers, to achieve the desired acoustic characteristics. The software can analyze the direction and intensity of sound sources within the auditorium, helping in the placement of speakers, microphones, and other audio equipment for optimal sound distribution. Odeon allows users to accurately model the behavior of sound reinforcement systems within the auditorium, helping in the design and optimization of speaker placement, coverage patterns, and sound distribution uniformity. Odeon provides virtual sound field measurements, allowing users to simulate and evaluate different acoustic scenarios. This helps in identifying potential acoustic issues and allows them to be addressed before the construction of an actual auditorium. Odeon can be easily integrated with architectural design software, enabling architects to evaluate the acoustic performance of different design options during the planning and design stages of the auditorium construction. Odeon auditorium software is a helpful tool for designing and optimizing the acoustic performance of auditoriums and concert halls, helping to create immersive and high-quality sound experiences for audiences.

Each hall was tested with the same components to ensure an accurate comparison post-simulation. In each model the sound source was placed 3ft behind the front of the stage. Receiver 1 (R1) was placed 60ft from the stage in the middle of the audience, and Receiver 2 (R2) was placed 120ft behind the stage located near the back of the hall. In simulations the materials remained the same for each hall. The stage is wooden planks over hallow air space. The Stage enclosure is ½ inch wood paneling. The floor is wood over concrete base. The roof is plaster over wood and joists. The walls also consisted of plaster, but over masonry instead. The audience being upholstered seats with medium density. Once the materials have been assigned, each hall was measured for a variety of acoustic considerations. While Odeon will be very useful in the future when designing a model, for this research the focus remained on how the EDT changes as tiers are added to the design, and what design accommodations need to be noted in response. As previously stated, EDT is a strong indicator of sound quality.

SIMULATIONS



HALL 1

R1 Results

EDT Average: 3.6 seconds

C(80): -4.6 dB

R2 Results

EDT Average: 4.5 seconds

C(80): -2.6 dB

Dimensions

Width: 80 feet

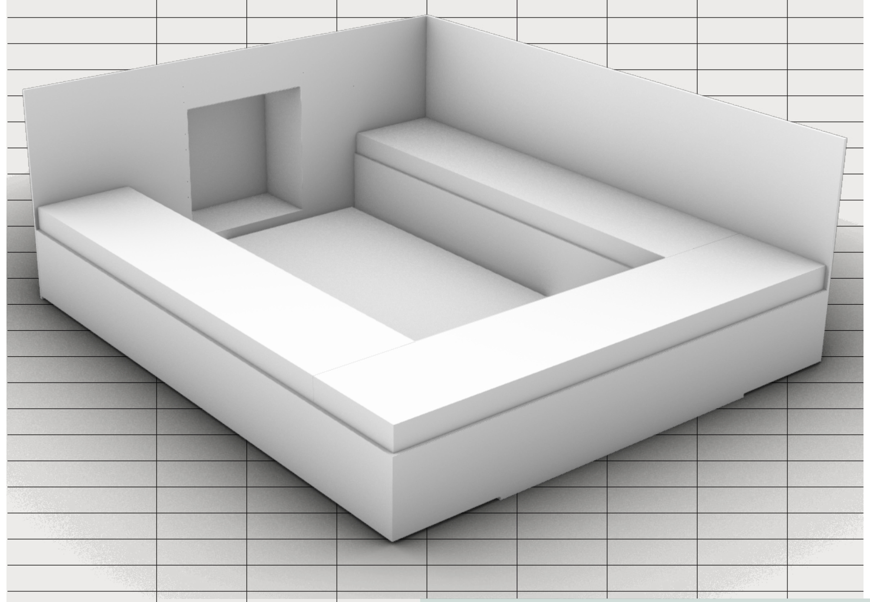
Length: 130 feet

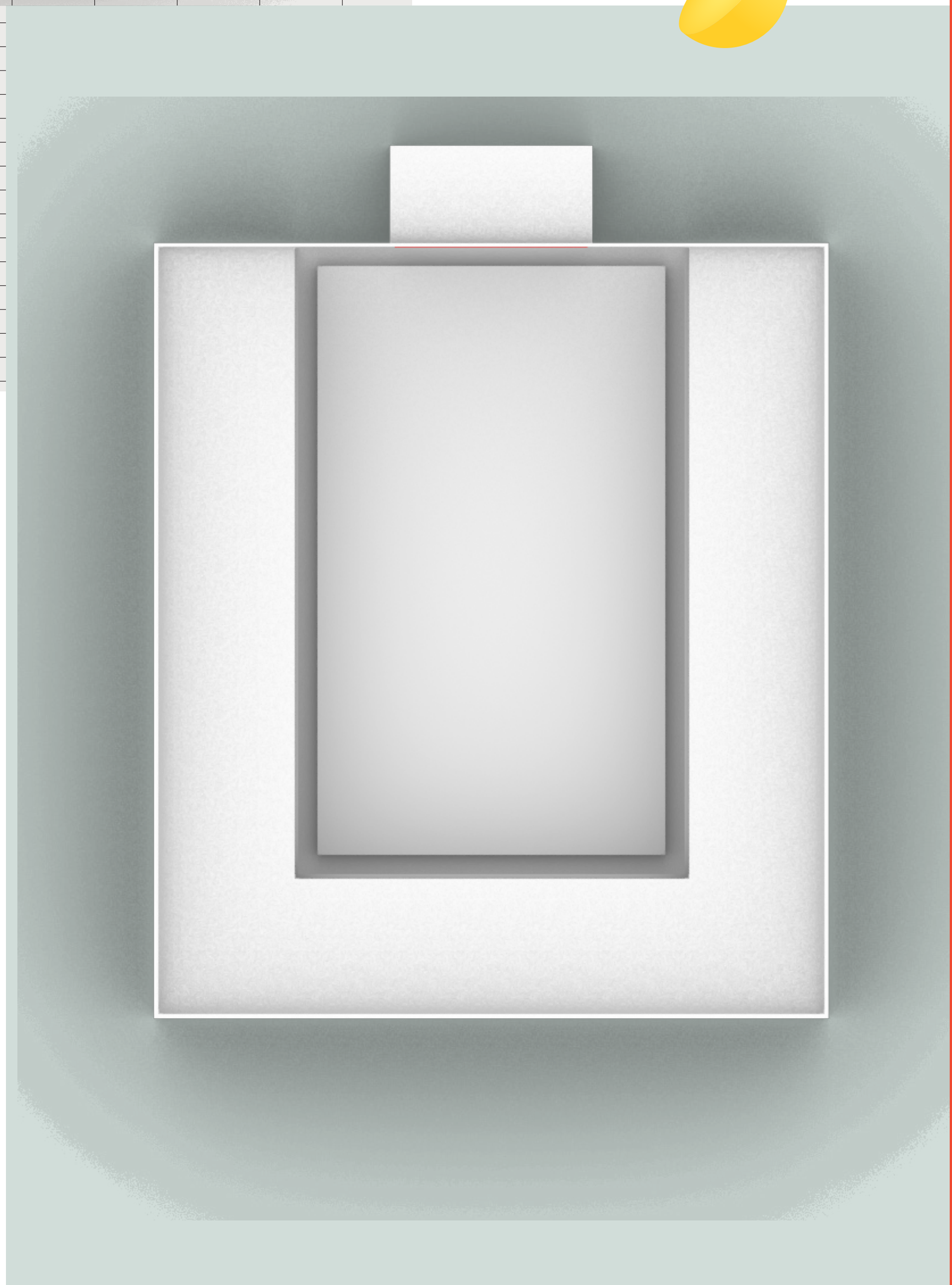
Height: 60 feet

For the first simulation the design was based off of the 3 iconic concert halls that all have similar shapes. I took the average off all their measurements to create this configuration.

The test of this model did not come out they was I was anticipating resulting in an EDT at both points that was much higher than expected. This can be attributed to the amount of open air and smooth design that rhino created. While the results were not anticipated they did highlight the important role that sound absorption treatments play in concert hall design. Through this test I was able to confirm the statements that I had previously read in literature, and now can move forward. The clarity of the hall can also be improved as the ideal goal is between 0.0 and -2.0 for good sound.

This design was meant as a base guide to see how much the acoustics change as you add more seating and increase the overall volume of a hall.





HALL 2

R1 Results

EDT Average: 3.6 seconds

C(80): -0.4dB

R2 Results

EDT Average: 2.31 seconds

C(80): 0.4dB

Dimensions

Width: 140 feet

Length: 160 feet

Height: 60 feet

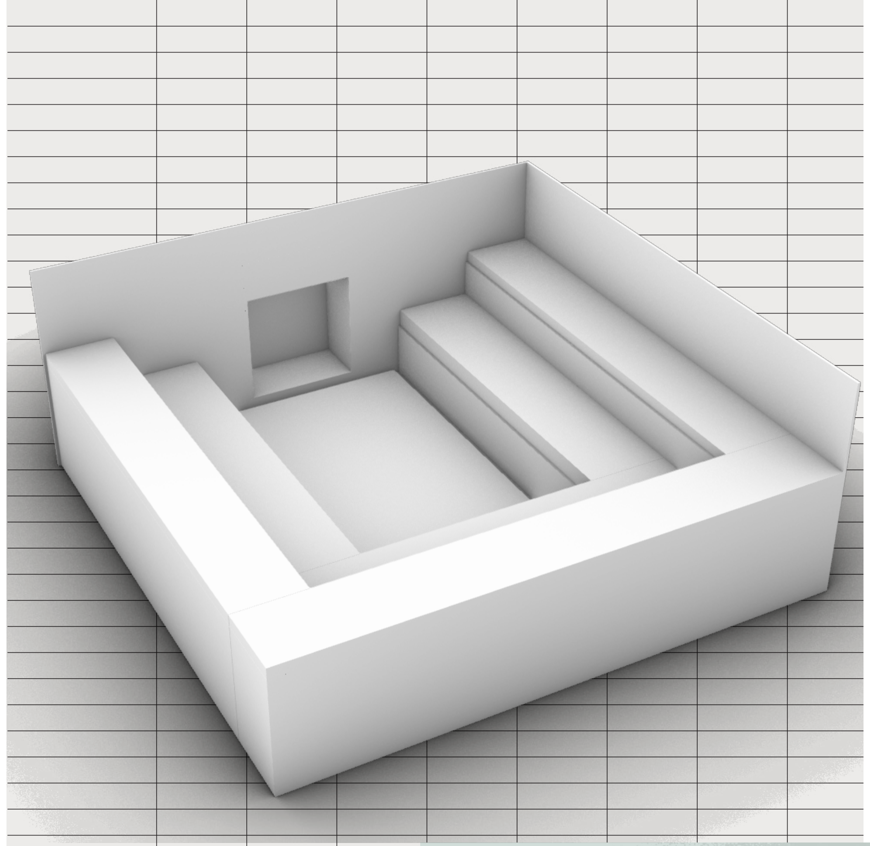
1 Tier of Seating

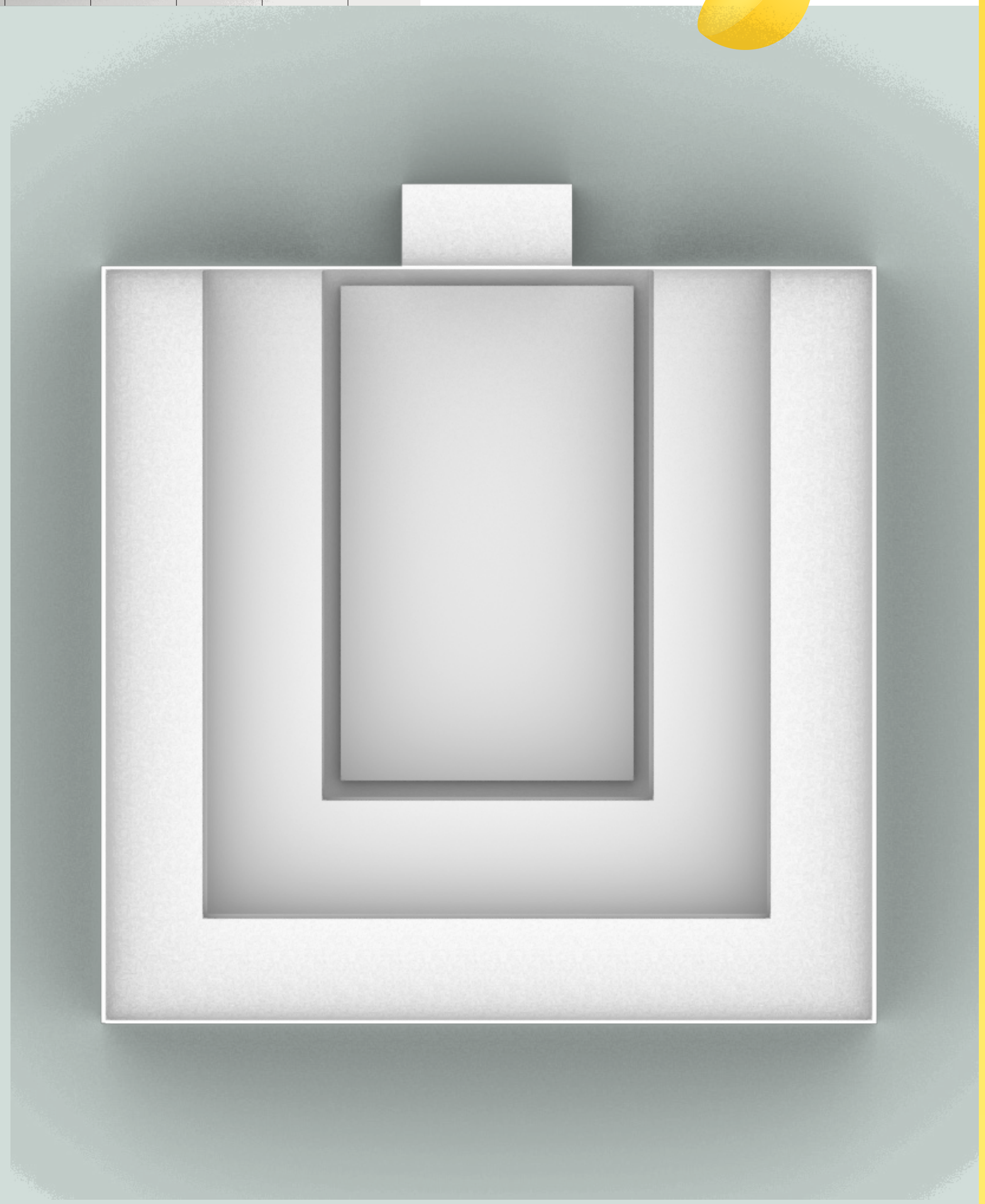
In the second simulation I added one 30ft wide tier of seating to the hall. This increased the size of the space while also introducing more sounds absorption to the space via the new seating.

The EDT decreased to a much more ideal level that is somewhat consistent with the big 3 halls. The introduction of new seating was able to lower this number as well as bring the Clarity to a more desirable goal. Out of these first 3 halls that are designed in a similar pattern this one performed the best.

Compared to the EDT of Concertgebouw in Amsterdam this hall is pretty close the 2.63 seconds time of Concertgebouw.

This test let me know that you can add more seating to a hall without compromising the acoustics.





HALL 3

R1 Results

EDT Average: 3.02 seconds

C(80): 0.4 dB

R2 Results

EDT Average: 3.14 seconds

C(80): 0.3 dB

Dimensions

Width: 190 feet

Length: 180 feet

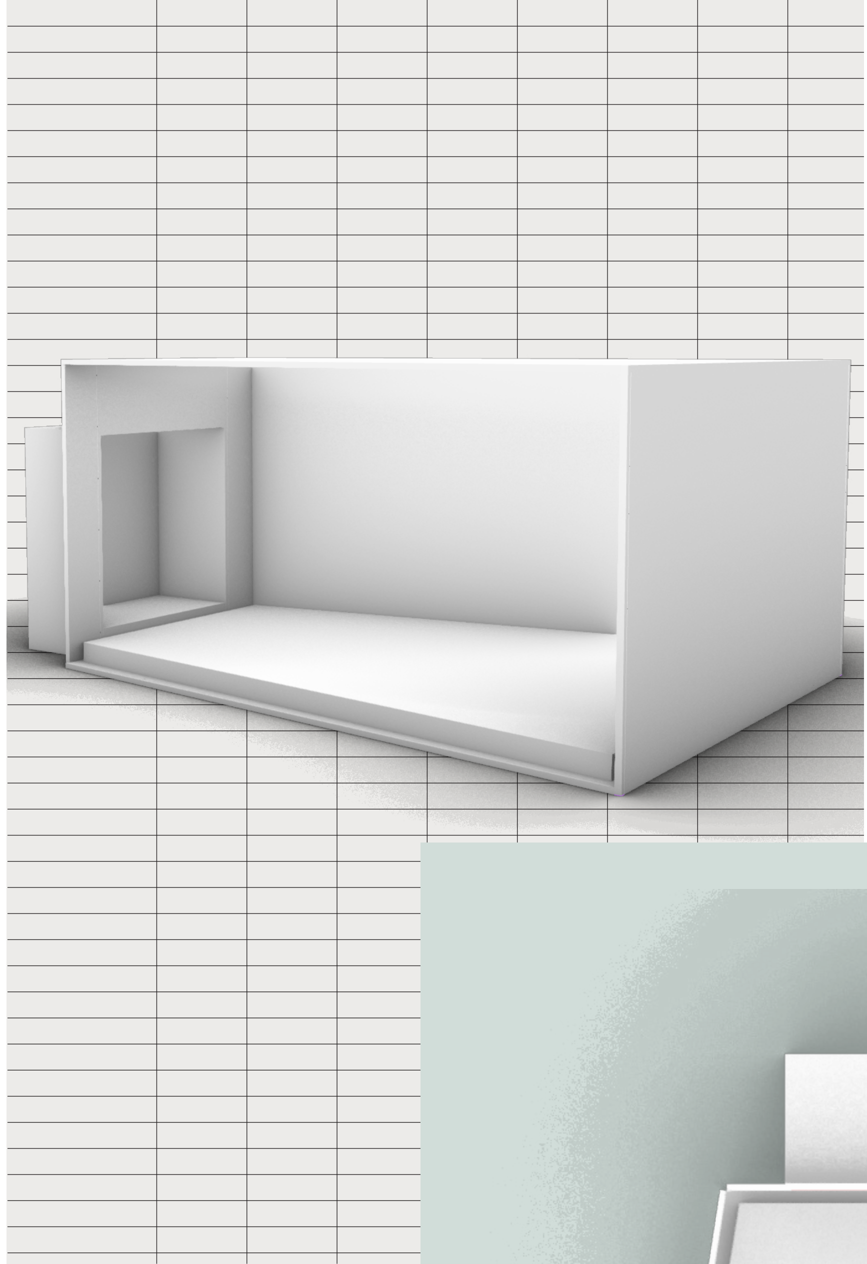
Height: 70 feet

2 tiers of seating

For the third test and additional balcony of seating was added to further increase the seating capacity of the hall. This upper tier is 25ft in width effectively increasing the size of the venue.

The EDT remains relatively consistent across the board with both points average being within 0.12 seconds of each other. The clarity of the hall also remained relatively close to that of hall 2. I was concerned that this hall was going to have unreasonably high results but they turned out to be much more realistic than anticipated.

Basing of the shoe box shape also seems to be a strong design choice no matter the size of the hall. It will most likely become a starting point for my design next semester.



HALL 4

R1 Results

EDT Average: 4.07 seconds

C(80): -3.3 dB

R2 Results

EDT Average: 4.26 seconds

C(80): -1.4 dB

Dimensions

Width: 100 feet

Length: 140 feet

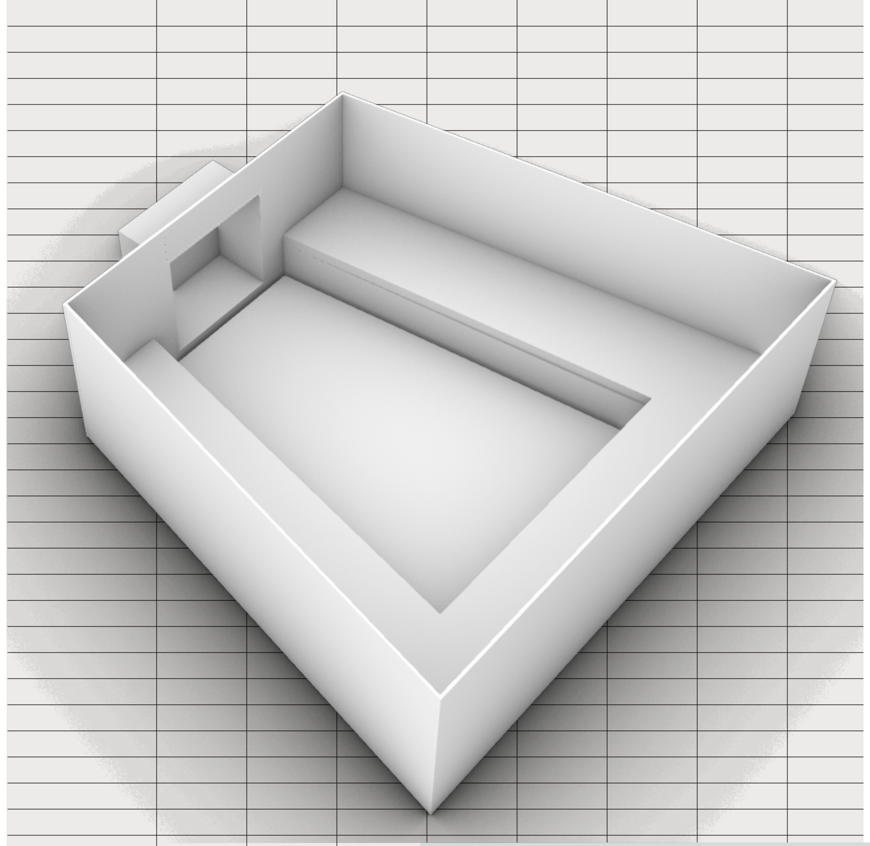
Height: 60 feet

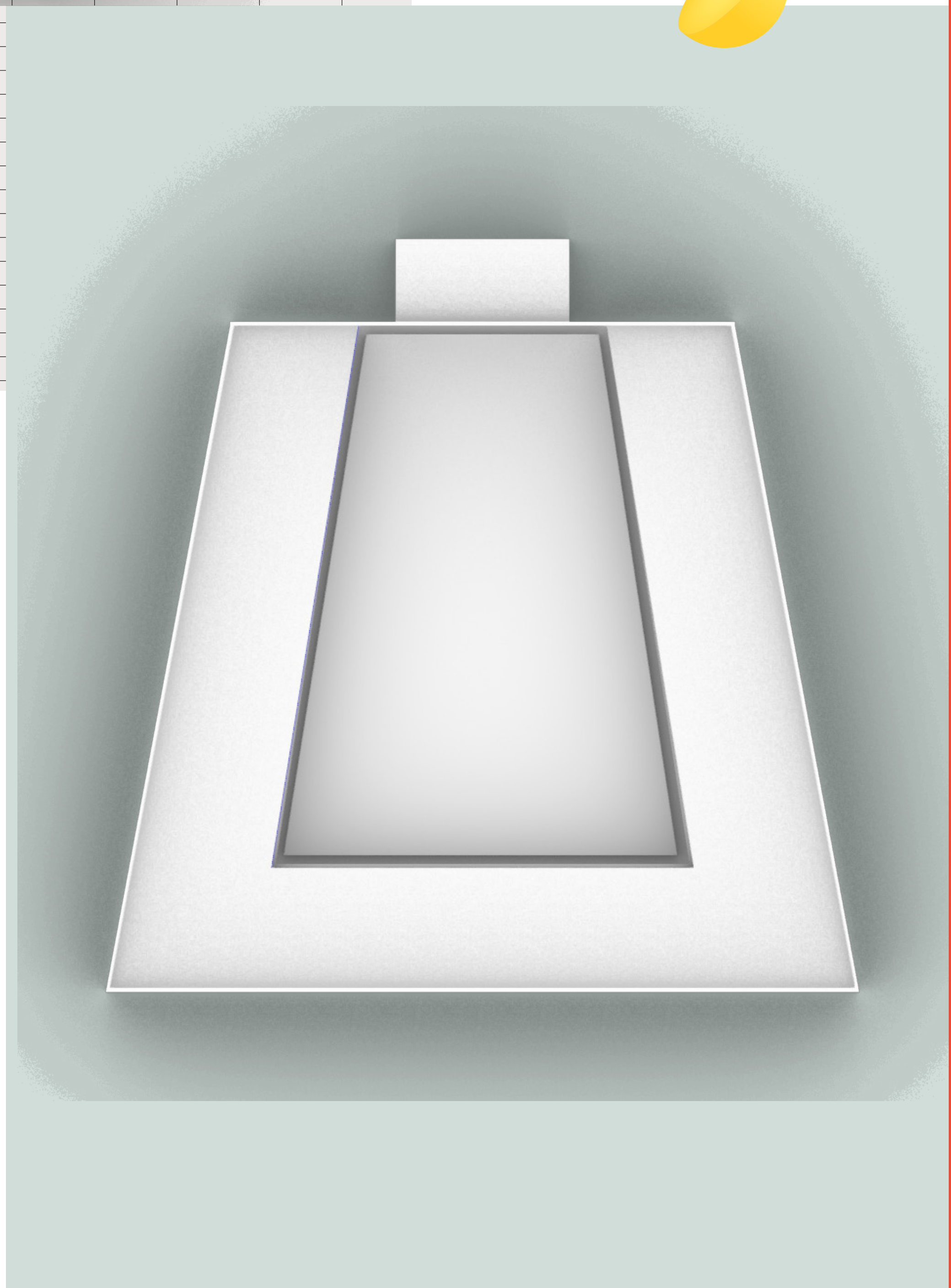
For hall 4 I stuck to a similar size to hall 1 but flared out the far end to from a trapezoidal shape. This was done in order to increase the seating capacity of the space.

The first test for this hall and shape came out okay, but not and good as hall 1 which means it may not be as ideal. The EDT is rather high compared to that of other halls studied, but once again this can be attributed to how simple in nature these models are.

The Clarity of this all aligned the most with what literature sated should happen. R1 had a lower responses than R2 which is typical.

This design may have potential for use but will likely need more accommodation to enhance the acoustics compared to halls 1-3.





HALL 5

R1 Results

EDT Average: 2.65 seconds

C(80): 0.2 dB

R2 Results

EDT Average: 2.71 seconds

C(80): 1.8 dB

Dimensions

Width: 160 feet

Length: 170 feet

Height: 60 feet

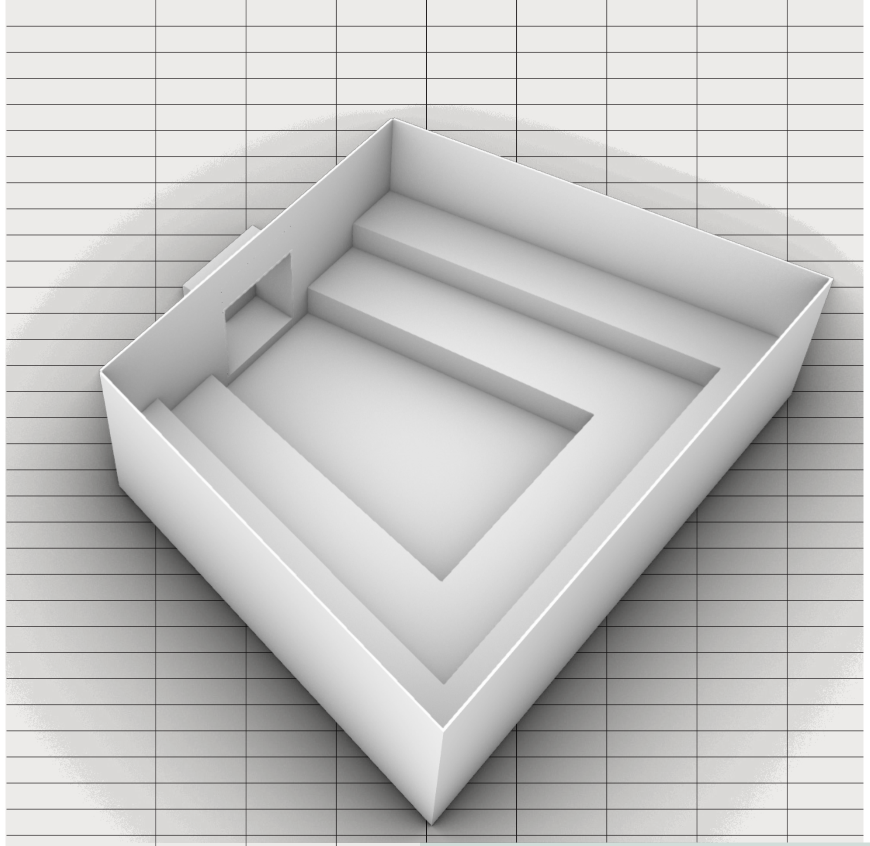
1 Tier of seating

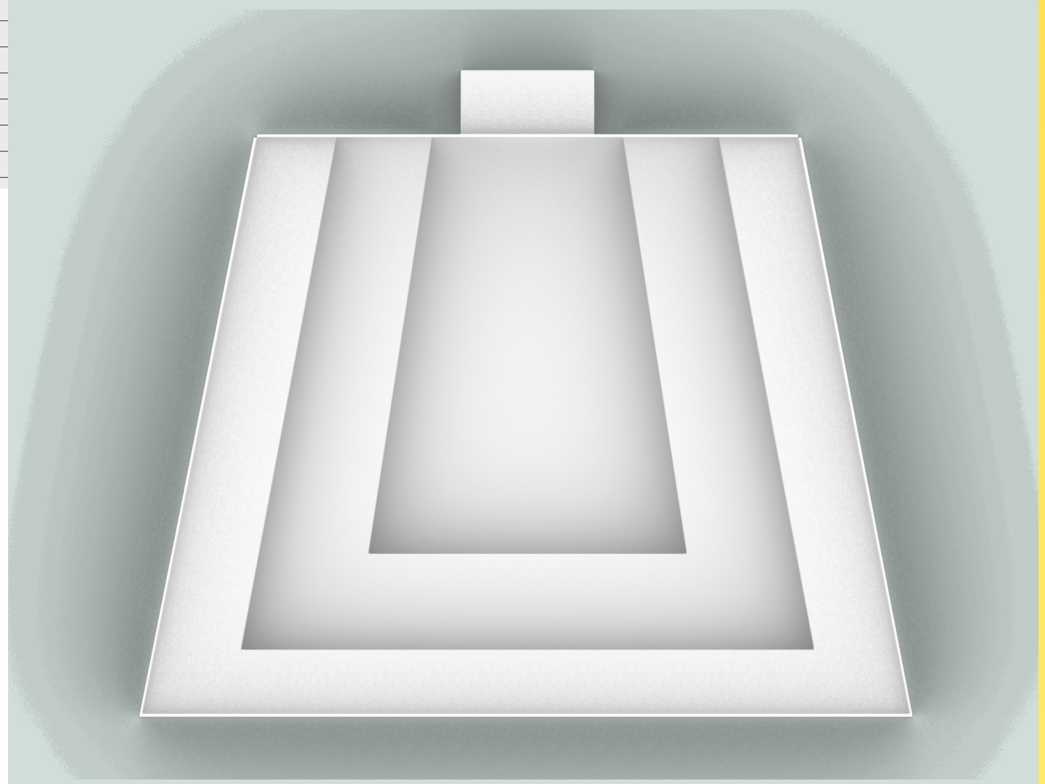
Hall 5, like hall 2, has an additional level of seating that is 30 ft in width.

The relationship between hall 1 & 2, and 4 & 5 have similar results in the sense that the additional layer of seating provides more absorption once again resulting in a better EDT.

Out of all 6 halls this one performed the best. It has the strongest and most consistent EDT across the hall making it an ideal candidate for the base of my design next semester.

The clarity of the hall is not the best but this is something that can easily be improved upon to create better acoustics within the space.





HALL 6

R1 Results

EDT Average: 9.72 seconds

C(80): -6.1 dB

R2 Results

EDT Average: 9.37 seconds

C(80): -3.7dB

Dimensions

Width: 210 feet

Length: 195 feet

Height: 70 feet

2 tiers of seating

For my final test I continued following the pattern, and added a second layer of seating to the hall. It was 25ft in width, and increased the height of the model by 10ft.

The results of this test were by far the most shocking. I was not expecting the EDT or clarity of the hall to increase so drastically . Between the added height and angular shape of the trapezoid the sound did not reflect well at all in the hall.

Moving forward I will most likely stick to the traditional shoe box design fro my project as they seem to provide the most ideal acoustics at any size.

CONCLUSION

From my research I was able to gather a large amount of critical information for my project. Literature provided a wealth of knowledge that I used as a baseline throughout. Once readings had been covered I was able to move on and study cases of different halls around the would . All of this knowledge led me to develop my prototypes for simulation.

The simulations provided insight as to how the acoustics will shift as the size of the space changes. Moving forward I plan to work with similar rounds of testing to develop a space that can morph itself depending on the type of entertainment that is taking place. Doing thin I will be able to design a music venue that has a lot of potential for utilization in the future.

Throughout this process I was able to become more familiar with an area of design that I have not yet explored. I became comfortable with new software that will be able to enhance my design next semester as well. Additionally as I move into the next phase of research I intend to get more custom with the layout of the hall to form the best design solution that I can. Odeon will allow me to do this and be able to inform how I go about laying out seating, balconies, materials, and sound altering treatments.

This is a rather experimental area of architectural design that has not been made common practice. This concept of morphing spaces to allow maximize utilization is something that can be carried over into other parts of the field as well. It could be beneficial to a variety of designs in the field.