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Title

Versatile Venue: How can the acoustics of a space be optimized for varied performances?

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MASTER OF ARCHITECTURE

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

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ABSTRACT

Live music and performance have been an integral part of the entertainment industry for decades. This research focuses on how the live experience can be enhanced, to benefit both the performer and audience. Utilizing historically effective design strategies, material choices, and acoustic comparisons in the design process to create a venue like no other.

The hall is designed with the optimization of acoustics in mind. This is focused within un-amplified performance halls which have the capability to transform into amplified halls. Simulations of the halls determined the acoustic capability within each, and what kinds of performances can take place. This allows for more versatility within the space, and more use than one singular venue can offer.

ACKNOWLEDGMENTS

I would like to thank Professor Mahalingam, whose knowledge and expertise were able to influence and guide the final project outcome, an accomplishment that would not have been possible without his assistance.

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LIST OF ABBREVIATIONS

RT ....Reverberation Time

EDT..Early Decay Time

ITDG..Initial Time Delay Gap

LIST OF SYMBOLS

°..Degree

1. INTRODUCTION

1.1 Problem Statement

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.

1.1 Research Questions

What's the ideal configuration for a performance venue for specific performance types?

Determining what the best design and materials for a variety of different performance types will be important. These include orchestra, symphony, woodwind bands, theatrical plays and performances, opera, speakers/comedian shows, and concerts (loud volume events). This will ensure that I design most events which will make the venue more useable.

How can architecture be used to form the way sounds move and are heard?

I need to not only look at the performance of specific shapes but also how the sounds propagate within it, and I may be able to discover to utilize a shape that hasn't been explored yet. This will also provide a better understating of acoustic propagation and can be used to inform my research and design process.

What can kinetic architecture provide in terms of spatial configuration flexibility?

This can provide an alternate route of research and design that I can become familiar with. Knowledge on this topic will elevate my design process to a more futuristic design and will provide context on how to design interior spaces with more versatility.

How can a venue be designed to maximize its use and acoustic capability?

I want to make sure that the venue is used as much as possible, and to accomplish this I must make sure that it can function for a variety of spaces.

1.1.1. Proposed Outcomes

From this work I expect to develop a venue that can accommodate a variety of performance types within the space. This in addition to how kinetics can be utilized to assist space will be the focus of the outcomes. I expect to create and develop a prototype structure for this new kind of venue.

This research would be able to provide more information on this world of architecture and can expand the use of kinetics. It could potentially be applied to a variety of spaces and structures in the world. It could create new ways to think about how we design spaces and how flexible they can really be. In the longer-term scope of things, using kinetics could become more common in design if allows for a beneficial way to transform a space quickly. Optimizing acoustics would also make a venue a desirable stop for many tourists. Being able to sit in performance hall and know that it has been modified to create an ideal listening experience for the user would be a way to design for the human experience and make architecture more impactful for the everyday person.

1.2.1. Aim

The goal of my research is to develop a performance center that can morph its structure to provide an environment that maximizes acoustics in accordance with the entertainment taking place in the center. Using kinetic architecture and acoustic analysis I plan to create the ideal venue that can accommodate this and maximize the acoustical performance of the venue.

2. BACKGROUND

2.1 Background

2.1.1 Measures of Acoustic Performance

A listener 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. Then comes the early sound, this is a combination of all the direct and reverberant sounds a listener hears in the first 80 milliseconds. This is followed by the reverberant sound which encompasses all the reflections heard after the first 80 milliseconds.(Beranek, 2004)

Aside from just sound, acoustics are comprised of many other factors. Certain halls have different performance requirements for the space, so acousticians measure sound to create the ideal performance space. One of the more flexible ones is reverberation time (RT). It is the number of seconds it takes for a loud tone 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 fit in with the music being performed it can become easily noticeable to the listener and make their experience less enjoyable. According to (Beranek, 2004) "reverberation to an acoustician, is the continuation of musical sound in a hall after the instrument that produced it ceases to sound." (Beranek, 2004 pg.20)The after ring that is only experienced in indoor venues, outdoors sound just 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. The lister hears the first direct soundwave, followed by a series of reflection waves. In one second these reelections 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 (Beranek, 2004).

Early Decay Time (EDT), also early reverberation time "the exact amount of time it takes for a sound from a musical note to decay 10 decibels after it is cut off, multiplied by a factor of 6"(pg. 20) the factor of 6 is used to allow comparison of EDT and RT. EDT is also better at indicating acoustical quality, because instruments are typically playing notes a in rapid consecutive order, which does not always allow for reverberation time to be heard.

Definition or Clarity "Name the degree to which a listener can distinguish sounds in musical performance." (Beranek, 2004 pg. 24) 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." (Beranek, 2004 pg. 25)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." (Beranek, 2004 pg. 26) the composer can also manipulate vertical definition. 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.

The initial time delay gap (ITDG) 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 an 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.(Beranek, 2004)

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 or not 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 discernable from other halls.(Beranek, 2004)

Texture They refer 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 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.

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 complement the overall shape of the hall and maximize sound projection to the entire audience. (Holden, 2016)

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.

Shape

Most 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.

Smaller Audiences provide better acoustics. 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.

2.1.2 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 they sound together. The reflecting surfaces around the stage affect blend the most and need to be designed to help the performers sound more harmonious. Ensemble is the performers' ability to play in harmony and unison, so they complement one another contributing to the acoustic sound as a whole. Reflectors around a stage should carry the sounds from one side to the other allowing performers to better hear one another. Risers are also used frequently to allow performers to better see each other on the stage, this also helps them maintain uniformity and ensemble when performing.

2.1.3 Architectural Design in Acoustics

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 too many smooth wood surfaces in hall with result in too much bass being absorbed as these materials tend to absorb low frequency sound. Brilliance is created from having prominent treble frequencies in sounds that decay slowly over time. These frequencies can be affected if the hall has too many sounds' absorbent materials, so it is best to find a strong balance when designing. The sound can have too much brilliance if electronic amplification is incorporated in a poor way. (Holden, 2016)

Acoustical Glare Sounds can reflect off of too many smooth surfaces and can take on harsh brittle quality. In order to prevent this many halls, have irregularities or ornamentation along the walls to help prevent this problem from happening. (Beranek, 2004)

2.2 Literature Review

Concert And Opera Halls

Concert and Opera Halls provide a large collection of 66 auditoriums from across the world. This book provides a large amount of information on a large collection of halls. 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, however 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 I will be able to cite expert opinions on different designs which will help me create conceptual configurations that I can run simulations on. The rankings also provide context on the best shapes, sizes, and layouts that work well for mostly musical performances.

I do need to be mindful of the subjective nature of the document. Due to this I can't base any scientific statements solely on the source, I need make sure I can support any findings from the book with other credible reports and sources, which focus specifically on acoustics parameters. I have discovered that many of the concert halls within the same category tend to have similar design trends, shapes, and materials, which is worth noting and I can conclude that there are certain shapes that make a more ideal environment as far as musical performances are concerned. (Beranek, 2004)

Architectural Acoustics

This book provides a large amount of information on how acoustics work and how to achieve high quality acoustic sound in a space. It walks you 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.

I think I will reference this most for baseline acoustic components. It can be referenced for such a variety of topics within acoustic design and will be one of my most used resources 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.

Overall, I think that this textbook will be a valuable resource to have. It covers the basics of acoustic design and provides other avenues to explore that I had not considered before. In combination with other sources of information it will be able to impact my research and design processes. (*Architectural Acoustics - North Dakota State University*, n.d.)

Acoustics of Multi-Use Performing Arts Centers

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 achieved. Insight is provided on what specific architectural considerations 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. (Holden, 2016)

2.3 Project Type

The project type will focus on a concert hall that can shift into different variations and accommodate a wide variety of performances. The design will be informed by the previously stated acoustic research, and the following case studies in section 3.4.

2.4 Project Issues

This project aims to create a venue that has more utilization than what we currently have. Most venues have one set configuration that limits what event they can host. By designing a project that can accommodate more performances, the space can be utilized more often, generate more revenue, and make a bigger contribution to the performance industry.

3. Methodology

3.1 Approach

To accomplish my goals, I will be using several different methods to conduct research. I will be doing a variety of different case studies on concert halls and performance venues from across the world. Doing this will allow me to collect and compare data relating to construction, materials, and location of venues. I will be able to then apply these to design concepts which I will analyze using Odeon This will give me the ability to experiment with a variety of configurations that will be combined into one versatile venue.

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 (step 1). This as well as most of my data will be sourced from literature and software programs. In addition to this I will also be researching kinetic architecture (step 3) and finding ways to utilize it with the parameters of my project.

3.1.1. Analysis

Using this data, I will configure optimal design and be able to improve them in Odeon. Odeon can simulate how sound will propagate through a space, and then provide acoustic parameters, graphs, and visual graphics. In addition to this information Odeon will also be used to determine the best use for active systems in the space. ("Features and Specifications," n.d.)

3.1.2. Conclusion

Odeon will provide me with analyzations of different spaces that will inform my overall research and design for the project. Completing consistent case studies will also provide a large source of data to compare and analyze music venues. All of this will hopefully result int the creation of a truly versatile venue with aspects that can be adapted and implemented into a variety of spaces.

3.2 Project Location

The project is in downtown Nashville, Tennessee. Nashville has a population of 683, 622, as of 2022(*U.S. Census Bureau QuickFacts*, n.d.), with projected growth. The population density sits at 1,452 per square mile, as of 2022(*Population Density Data for Nashville-*

Davidson, TN - Population on the Open Data Network, n.d.), also with a trend of projected growth. Nashville has an overall mild climate that can experience higher temperatures in the summer months. The annual high is 70° F and an annual low of 49° F. There is an average snow fall of 7 inches, and 47 inches of rain annually(*Weather Averages Nashville, Tennessee*, n.d.).

3.3 Specific Site

The site is located at 312 1st Ave S, Nashville, TN, 373201. It is approximately 546,031 square feet and is zoned to DTC. DTC is described as "intended to provide…a mix of compatible land uses that provide opportunities to live, work and shop within the neighborhoods of downtown. In order to create a more sustainable downtown, the DTC emphasizes regulating the height, bulk and location of a building and the context of the building in relation to its surroundings or other nearby buildings" also stating that building must have a minimum height of 25ft at the street front. (*Downtown Community Plan | Nashville.Gov*, n.d.)

The downtown Nashville area is an ideal place for a music venue. The walkability score of the city is a 98 (*Nashville TN - Walk Score*, n.d.) with easily accessible transit lines around the site, and plenty of parking in the area. It is also close to historic places such as the Country Music Hall of Fame, Grand Ole Opry, and Ryman auditorium; all places deeply rooted in musical history and connected to the city as well.

3.4 Case Studies

I will be completing several case studies 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.

3.4.1 Musikvereinssaal

Also referred to as Grosser Musikvereinssaal or Musikverein, this hall is one of the oldest in the world. Located in Vienna Austria, it originally opened its doors in 1870, and has been a source of entertainment since. It was designed by Theophil Ritter von Hansen in the late 19th century and has become well-known as one of, if not the best music halls in the world.

The hall has excellent acoustics and is considered by many conductors and musicians to be the greatest in the world. This is due to the rectangular shape and high ceiling which allows for such an ideal reverberation time. The materials used also play a role in how successful the sound is. The interior is almost completely plaster which helps the sound to be diffused uniformly around the hall. In addition to this there are many irregular surfaces and ornamentation on the walls and ceilings which also benefit the acoustics. The hall is louder than many others, which can result in poor sound music if the musicians are unaware, and do not play accordingly.(Farina et al., 2008)

The occupied RT is 2.00 seconds, the unoccupied RT is 3.05 seconds, and the unoccupied EDT is 3.04 seconds. It is mostly used for orchestra and solo performances and takes on the classic shoebox shape. The hall can seat up to 1,680 occupants and has a volume of 529,720ft^3. Materials are comprised of plaster on brick for both the side and rear walls, plaster on spruce wood for the ceiling, plaster on wood for the balcony fronts, and wooden flooring throughout. The seats have a wooden base, porous upholstery, and a 4-inch cushion; rear seats are made of just plywood. The stage is made of wooden risers over a wood stage, which is 39 inches tall. The stage enclosure is made of wood as well, with 200ft2 of draping to add sound absorption to the hall. (Beranek, 2004)

3.4.2 Royal Albert Hall

Royal Albert Hall is in London, United Kingdom, and opened in 1871. At the time the project cost around $10,200 to complete and was a gift for the queen at the time. Francis Fowke was the initial architect that worked on the project but passed during the design phase. Lieutenant Colonel H. Y. D. Scott took over and completed the project after Fowke passed.

The hall has had many acoustical challenges over the years that relate to the overall size. It is four times larger than any other well-liked concert hall but can hold double or triple the occupants as most others, making its use much more versatile. The biggest problems to come from the size were an increase in echoes and a decrease in loudness of direct and early sounds waves, as they must travel much farther compared to other halls. To combat the echoes a large velarium cloth was hung up until 1949. This cloth was deemed ineffective with some patrons claiming that the echoes had even gotten worse. The problem was finally addressed in the late

1960's. 134 'flying saucers' were hung from the ceiling which were able to suppress the echoes and improve the direct and early sound paths, particularly at the upper levels of the hall.(*Our History*, n.d.)

The occupied RT is 2.41 seconds, the unoccupied RT is 3.08 seconds, and the unoccupied EDT is 2.65 seconds. These statistics are impressive considering its size and are a testament to how any spaces acoustics can be manipulated with sound absorption techniques. It is used for a wide variety of performances which include pageants, lectures, exhibitions, choral performances, symphony, rock/pop concerts and solo recitals. The hall can seat up to 5,222 occupants and has a volume of 3,060,016ft^3. Materials are comprised of plaster on structure for the ceiling and walls, a perforated skin on a backing of mineral wool for the inner dome on the ceiling. Balconies made of concrete with wooden floors, and a 1-inch floor on wooden joists over airspace with carpeting for the main arena. The stage is thick wood over airspace, with a reinforced glass canopy. The saucers are made of glass reinforced plastic with a 1.5-inch blanket of glass fiber on top. Seating is upholstered on the top, back, and front with the rest of the chair made of wood. (Beranek, 2004)

3.4.3 Concertgebouw

Concertgebouw was opened in 1888 in Amsterdam, Netherlands. This hall is known for its excellent acoustics, making it one of the best in the world. The project cost around $98,800 around the time that it was built and was designed by A. L. van Gendt.

Concertgebouw is considered to have some of the best acoustics in the world. 20% of the seating is on the upper stadium steps behind the orchestra, with the rest of the audience is seated in front of the stage in removable chairs. The irregular walls and ceiling which have deep coffers create the ideal environment to produce excellent sound diffusion which allows for the reverberation time to be 2.0 seconds. The dimensions of the hall are larger than others in the same caliber, with a much higher stage height than any other hall I have researched so far. Beranek prefers the acoustics of the balcony more than the floor but claims that if you enjoy music that consumes you when listening there is no hall superior to his one.

The acoustic measurements are ideal with and occupied RT of 2.00 seconds, unoccupied RT of 2.59 seconds, and an unoccupied EDT of 2.63 seconds. There is a consistent variant of performance in the hall, with orchestra being one of the more frequent. It is in a classic shoebox shape, has a volume of 663,210ft^3, and can house 2,307 occupants. The materials consist almost exclusively of plaster on supporting materials making the ceiling, and all walls; both of which have ornamentation and irregularities throughout. The floors are 5-inch concrete on top of wooden boards with no carpeting. The stage is one of the tallest at 59 inches in height, made of heavy wood that sits on top of an open-air space. The seating is made of thick hard weave upholstery, and the hall has 700ft^2 of draping as an added layer of sound absorption. (Beranek, 2004)

3.4.4 Boston Symphony Hall

The Boston Symphony Hall is in Boston, USA. It was opened in 1900 and is one of the best, alongside Concertgebouw, and Musikvereinssaal. This project cost $771,000 to build, and was designed by McKim, Mead, and White. Additionally, it had an acoustics consultant Wallace C. Sabine who played a key role in making sure it has the best acoustics in the USA.

The Boston Symphony Hall is one of the best in the world. It has an excellent ensemble that responds well to the orchestra. The sound is warm, clear, live, brilliant and just the right level of loudness to engulf the listeners. Many conductors and musicians agree that it has the best acoustics of any hall in America. This can be attributed to several design features that make it so successful. The shape of the hall is classic and known to work well, and the reverberation time was determined using Sabine's equation and methods. This equation also determined the height of the coffered ceiling which helps to control the acoustics. The dimensions are also limited to create a sense of intimacy within the space. The seats have very minimal upholstering, which is not a common occurrence within the hall, but they are designed in conjunction with the other materials, so the cloth material is not necessary to absorb the sounds. All these components allow the hall to project sound across the space uniformly, making it so great. (Beranek, 2004)

The occupied RT is 1.9 seconds, unoccupied RT is 2.52 seconds, and has an unoccupied EDT of 2.37 seconds. The hall mainly hosts orchestral performances and soloists and can accommodate 2,625 patrons within its walls. It has a much smaller volume than the previous halls with 309,003ft^3 of space. The materials consist of 0.75-inch plaster on a metals screen for the ceiling, and flat concrete floors with thin carpeting on the main walkways. 30% of the walls are plastered on metal lath, 50% are plastered with a masonry backing, and 20% consist of 0.5-1.0-inch wood paneling. The stage is 54 inches tall and made of 1.5-inch wooden planks that have 0.75-inch flooring on top, all floating over and large open airspace. The stage enclosure is also made of wood paneling that ranges from 0.5-1.0 inches thick. The seats are solid wood with cushions made of hair wrapped in leather on the armrests and seats. (Beranek, 2004)

3.4.5 Christ Church Town Hall

Christ Church Town Hall is located in Christ Church, New Zealand. It opened its doors in 1972 and cost $167,200,000 to complete. The Architects were Warren and Mahoney, with acoustics consultant Dr. Harold Marshall. (*Warren and Mahoney*, n.d.)

Christchurch town hall was one of the first to incorporate a new design concept by Harold Marshall. The design focuses on using spatial reflectors to immerse the audience by reflecting the early sound. The hall has 18 tilted free-standing panels that are used to execute this technique, in combination with a large sound reflecting canopy that hangs over the performance area. The balcony soffits incorporate the sound reflectors as well. accomplishing the task of delivering clear sound to the audience. The hall has an elliptical shape that is well balanced by all the reflectors. The benefits of the shape include good audience sightlines, and it makes the hall seem intimate even though it can host over 2500 guests. This design does have its flaws, it focuses so much on enveloping the listener in an early sound that when the music comes to a stop the reverberation in the hall feels weak compared to others.

It has an occupied RT of 1.9 seconds, an unoccupied RT of 2.34 seconds, and an unoccupied EDT of 1.89 seconds. It has an elliptical shape with a volume of 723,950ft^3, and can seat 2,662 people. The most frequent uses include orchestra, music recitals, choral performances, and speech events. Both the walls and ceiling are made of solid concrete. The stage enclosure is made of 1-inch-thick wood, with a stage that is 52 inches high, and made of 2-inch wood flooring over an open-air space. The seating is upholstered on the fronts and backs, with the rest of the chairs being made of wood. There is an irregular shaped canopy that is 24ft above the stage. The canopy as well as other reflectors are made of 1-inch-thick wood that has been heavily braced. (Beranek, 2004)

3.4.6 Bridge Water Hall

Bridge Water Hall is located in Manchester, UK. The project took $46,087,860 to be completed and opened in 1996. The hall was designed by Renton Howard Wood Levin who worked with Arup Acoustics to create its unique design.

The Architect aimed for a design that would allow for most of the seats to be able to see the stage. Because of the vineyard style of the seating most occupants can view the full orchestra, and stage with a view seat not achieving full visibility. Each tier of seating provides sound reflections to the spectators in combination with several irregularities that promote the diffusion of sound. The height of the ceiling also provides enough volume to the hall allowing for a mid-frequency reverberation of 2.0sec when the hall is fully occupied. (Beranek, 2004)The ceiling was constructed with an array of two-way spanning trusses that provide the appropriate sounds diffusion in the space. The hall is able to deliver a strong balance of clarity, loudness, and intimacy that is necessary for classical, symphonic, and choral music. To achieve this the hall is encased by noise protection from the surrounding roads and railways. The lower levels have offices and foyers which help to create a barrier from external sounds. Bridgewater hall has a limestone-clad double skin, which is able to insulate the upper levels from airborne noise where there is no room to construction additional buffers. (*Bridgewater Hall*, n.d.)

The building is made out of reinforced concrete and has been "molded like a vast sculpture" (2). This causes the walls to have more mass and density, improving the acoustic sound quality. In the main auditorium there is an earthquake system that sits underneath the foundation. This system is able to insulate the auditorium from outside noise and traffic to further improve the sound quality within.

Bridge Water Hall has an occupied RT of 2.00 seconds, an unoccupied RT of 2.44 seconds, and an unoccupied EDT of 2.40 seconds. It has a volume of 882,500 ft^3 and can hold 2,357 occupants. It has hybrid shape of a shoebox and vineyard style. It hosts many musical events including symphonic, choral performances, concerts, and chamber music. The materials consist of precast concrete panels on the ceiling, walls, and balcony fronts made of plaster. The floors are oakwood that has been embedded in concrete. The seating is wood on metal frames with perforated upholstery on the cushion and backrest. The stage is made of tongue-and-groove boards over air space with a suspended canopy made of curved glass panels, some having adjustable heights. Other reflectors throughout the hall are made of 1.2-inch glass reinforced gypsum board. (Beranek, 2004)

3.4.7 Tokyo Opera City Hall

Tokyo Opera City, Concert Hall is located in Tokyo Japan. It opened in 1997 and has a rather unique ceiling shape. The architects were NTT Facilities INC., Urban Planning and Design Institute. Co., TAK Associated Architects INC, with acoustical consultants Tanekaha Corporation research and development institute, and Leo Beranek.

The Tokyo Opera City has an unusual shape with a pyramidal shape that reaches a peak of 92ft in height. It is the first hall to utilize a new set of acoustical parameters that were developed in the last 60 years. This broke down the previous notions that excellent acoustics could only be achieved by replicating the iconic shoebox shape. Architects used CAD software to adjust the interior dimensions and sounds reflections within to control when sounds reached the listeners. A 10:1 scale model was developed to ensure the desired reverberation times and bass response were ideal. The hall embodies superior levels of intimacy, clarity, spaciousness and warmth. It is said that at the grand opening in 1997 every audience member was in awe at the acoustics, including the emperor and empress of Japan.

Due to this process, they were able to achieve ideal acoustics with an occupied RT of 1.96 seconds, an unoccupied RT of 2.80 seconds, and an unoccupied EDT of 2.69 seconds. The hall has a volume of 540,314ft3 with a seating capacity of 1,632 which is a bit smaller than previous halls. It has a rectangular base that flows into a pyramidal ceiling, and most commonly hosts chamber music, symphonic concerts, and soloists. The materials consist of two layers of glass fiber reinforced gypsum board each 0.4in thick, and one layer of silicated calcium board that is 0.24in thick on the ceiling. Walls made of 0.35-inch plywood over a wooden core. The balcony soffits are comprised of two layers of gypsum plasterboard 0.5-inch thick, one layer of glass fiber reinforced phenolic foam board 0.31-inch thick. The floors are one layer 0.6-inch thick of tongue and groove wood flooring, and one layer of 0.5-inch plywood over concrete. The stage floor is one layer of tongue and groove wood flooring 0.6-inch thick, and one layer of plywood 0.5inch thick, over airspace. 65% of the seat's backrest is covered in cushion, with a seat base that has a 3-inch-thick cushion. (Beranek, 2004)

4. Results and Conclusions

For the project itself a schematic approach was taken. This was to allow for a more in-depth exploration into the halls themselves and what potential transformations were possible.

4.1 Final Project Description

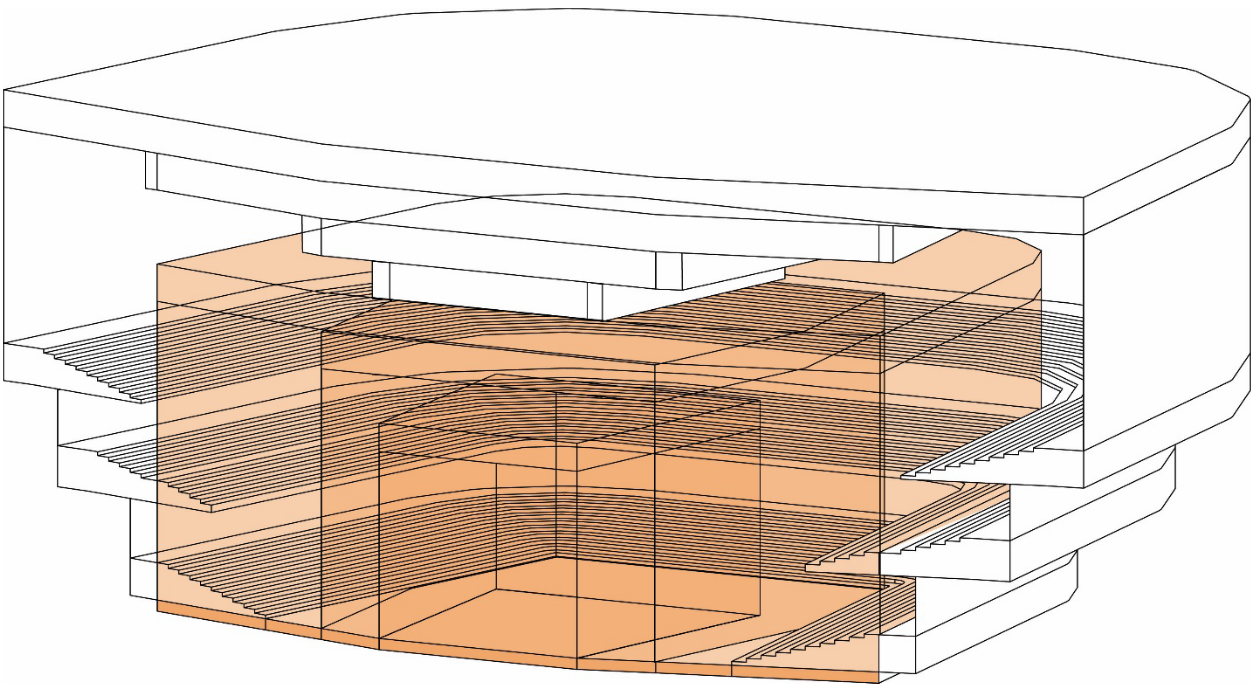

Figure 1 - Perspective View (Entire Hall)

As Previously mentioned, a schematic approach was taken. Above is an image that encompasses the overall hall design. There are a total of four different configurations the hall can transform into, each serving their own purpose. The hall can seat up to 4800 guests, and its maximum potential. Form Z was used to create all four models, two of which were then analyzed in Odeon.

To achieve my acoustic goal, I began modeling based off previous simulations and case studies. Throughout the process over 40 different halls were analyzed until the desired acoustics were reached. This then allowed me to model the rest of the hall and create a conceptual design for the interior. Material choice was also an important factor when designing. Throughout the process plaster was used on the walls and ceiling with the floor and stage comprised of a variety of wood.

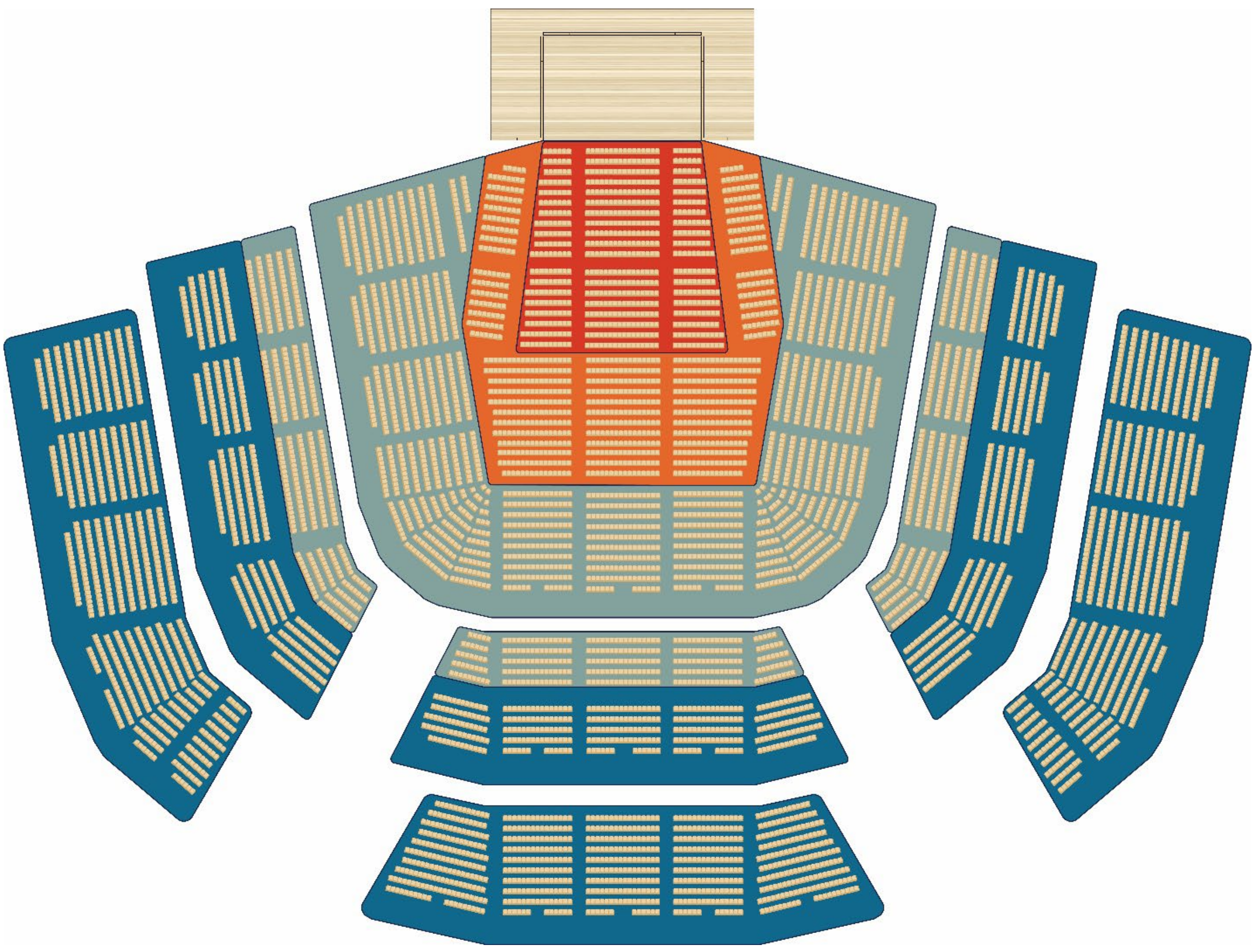

Figure 2 - Expanded Seating Plan

4.2 Designing a Versatile Venue

The goal of the project was to create a musical venue that could transform into a different size allowing for a wider range of performances to take place. There was a goal to focus on acoustics to make the smaller halls acoustically strong, making the hall a place artists want to perform. These goals were met by creating a variety of different halls to find the ones that would perform the best. Both smaller unamplified halls have reverberation times that are within the goal range, and the four varied configurations allow for a wide variety of goals to take place. Thus, creating the ideal venue concept originally sought after.

4.3 Project Design and Documentation

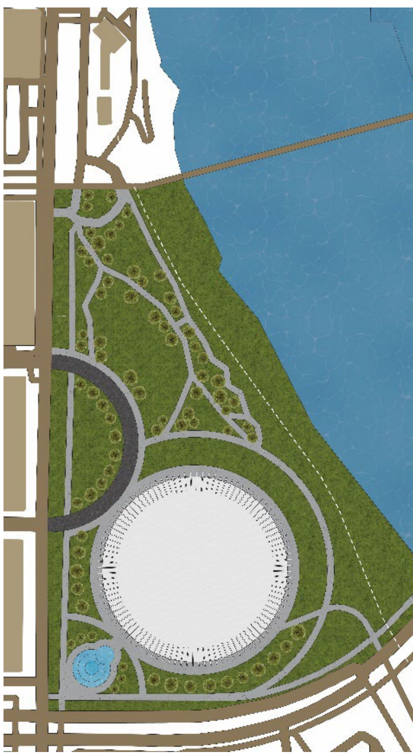

Figure 3 - Site Plan

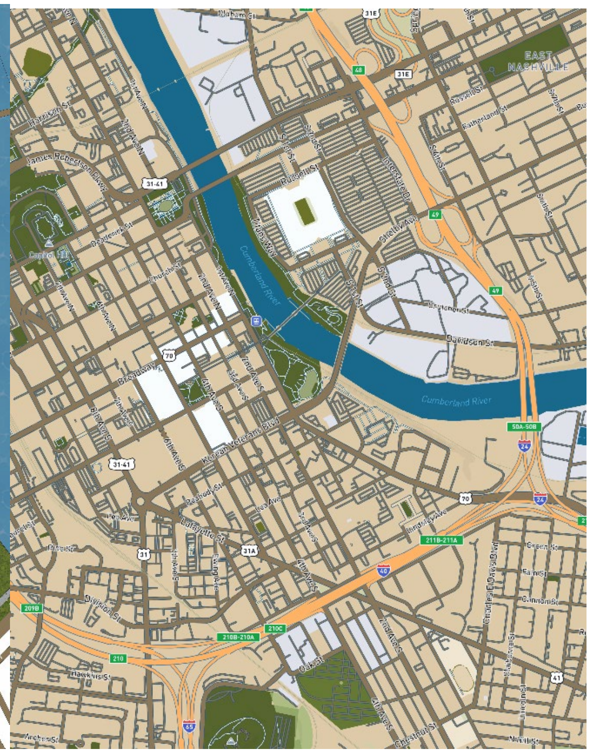

Figure 4 - Site Context

The above images show a simple site plan for the project as well as the surrounding context.

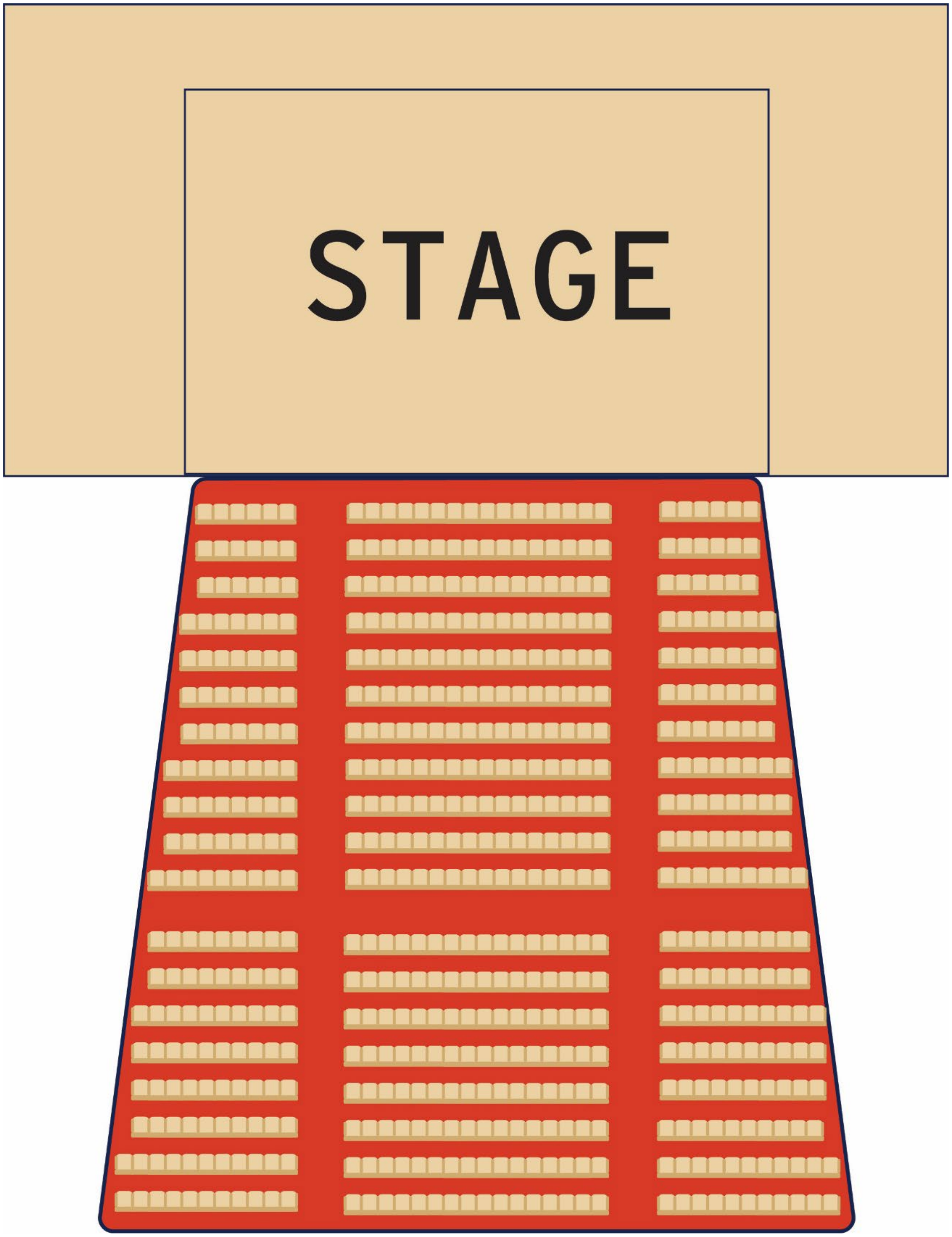

Figure 5 - Hall 1 Seating Plan

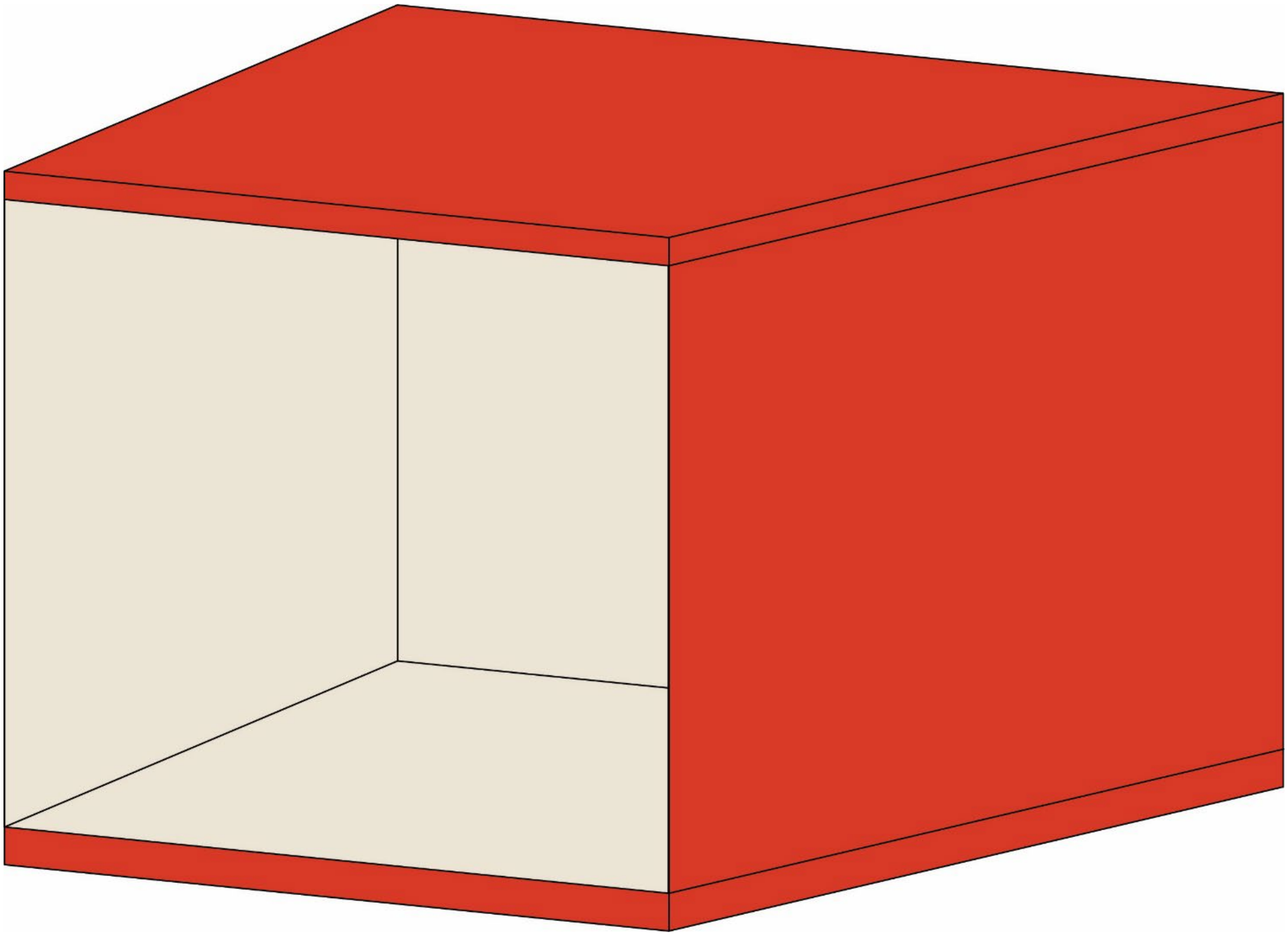

Figure 6 - Hall 1 Perspective View

Hall 1 has a capacity that ranges from 480 to 620 dependent on the stage configuration. Its intended uses include opera, ballet, speaking, and soloist performances. This is an unamplified hall meaning performances should not have to use electronic enhancements. When tested in Odeon 5 different response points were used. The overall RT was 1.85 making it ideal for its intended use. In addition to this the points all had relatively similar responses showing a consistent listening experience throughout the hall. These results are illustrated in the charts below.

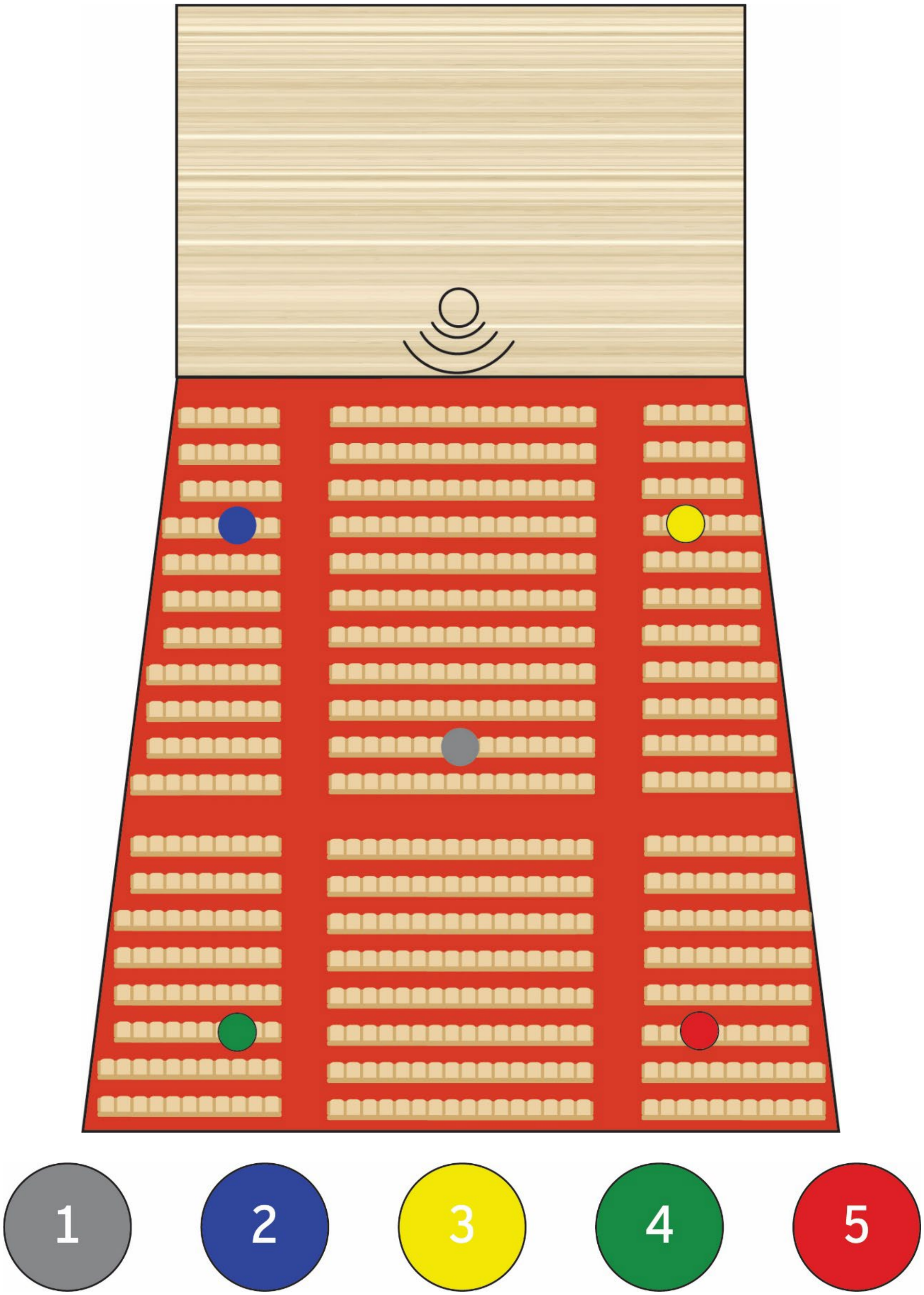

Figure 7 – Hall 1 Response Point Layout

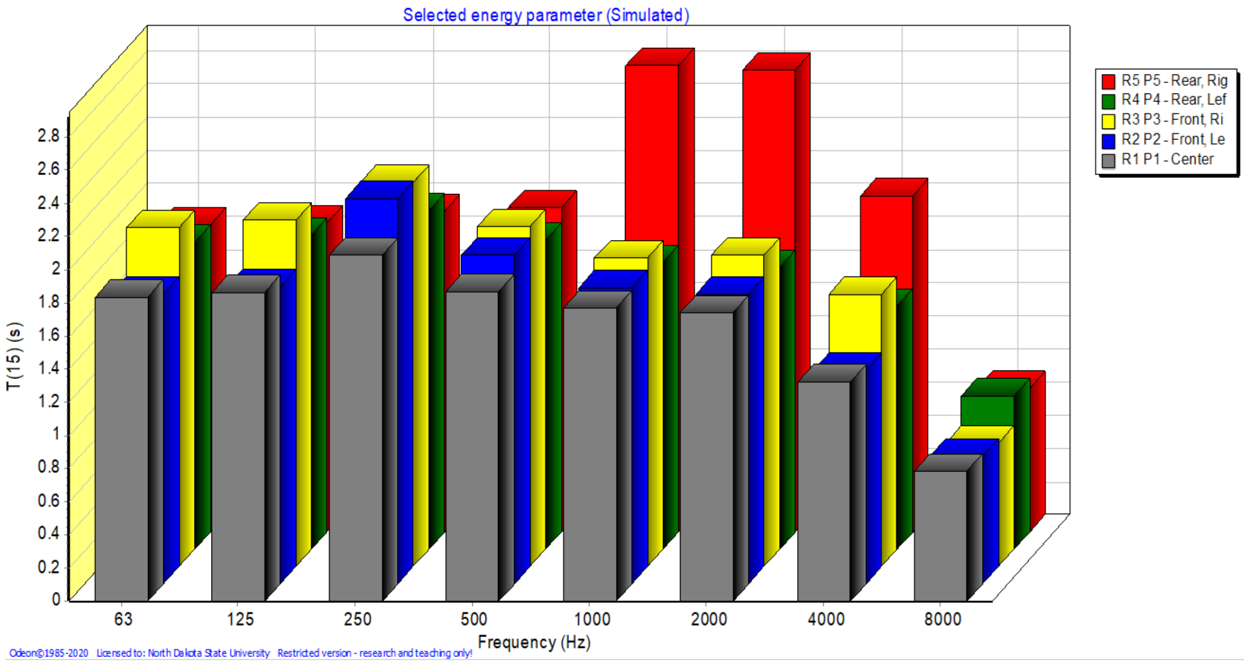

Figure 8 - Hall 1 T (15) results from Odeon.

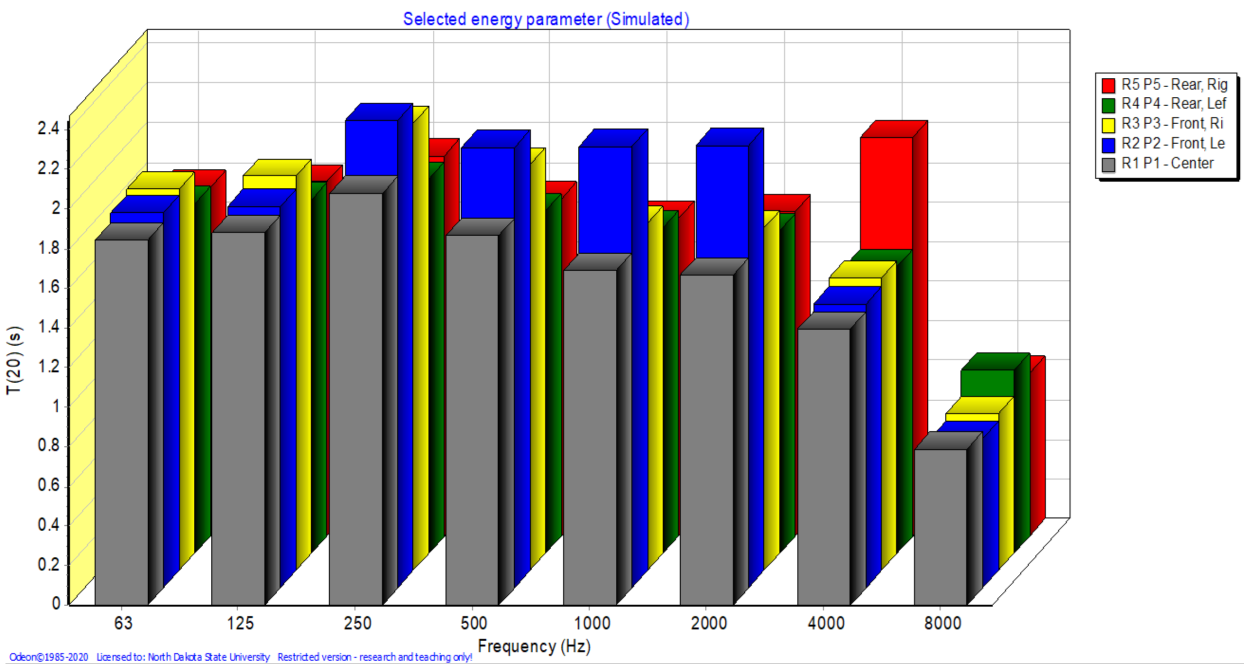

Figure 9 - Hall 1 T (20) results from Odeon.

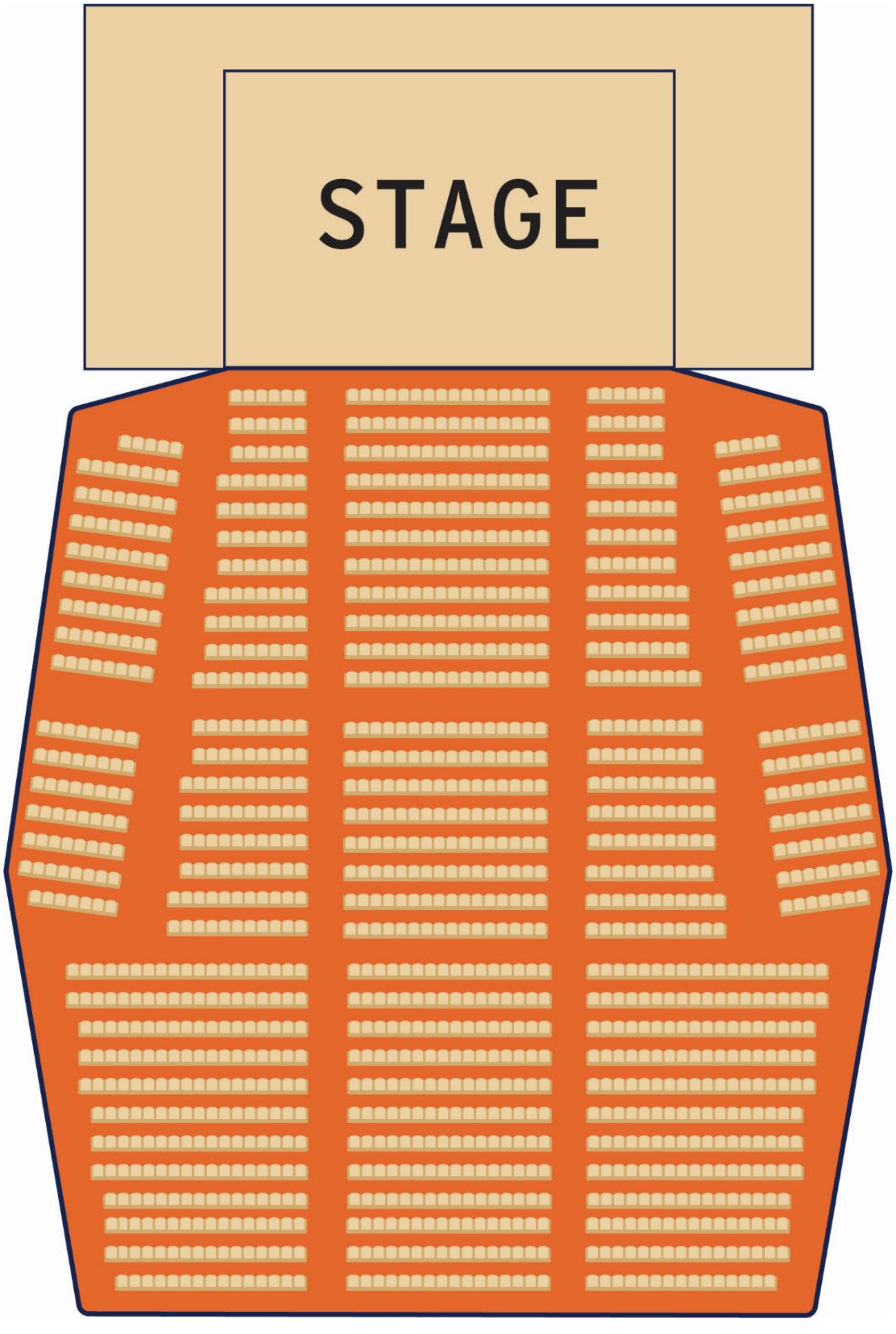

Figure 10 - Hall 2 Seating Plan

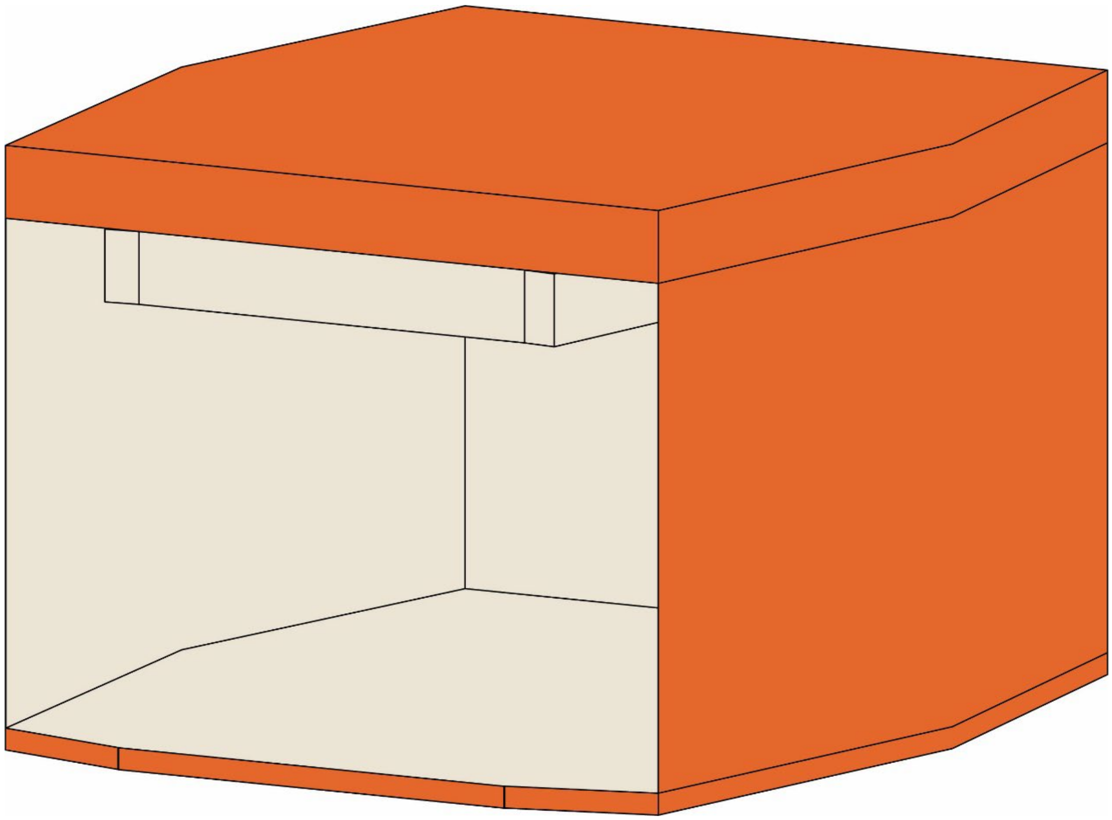

Figure 11 - Hall 2 Perspective View

Hall 2 has a capacity that ranges from 1300 to 1450 dependent on the stage configuration. Its intended uses include opera, ballet, speaking, theatre, soloist performances, symphony, and orchestra. This is an unamplified hall meaning performances should not have to use electronic enhancements. When tested in the Odeon 5 different response points were used. The overall RT was 2.1 making it ideal for its intended use. Again, the points all had relatively similar responses showing a consistent listening experience throughout the hall. These results are illustrated in the charts below.

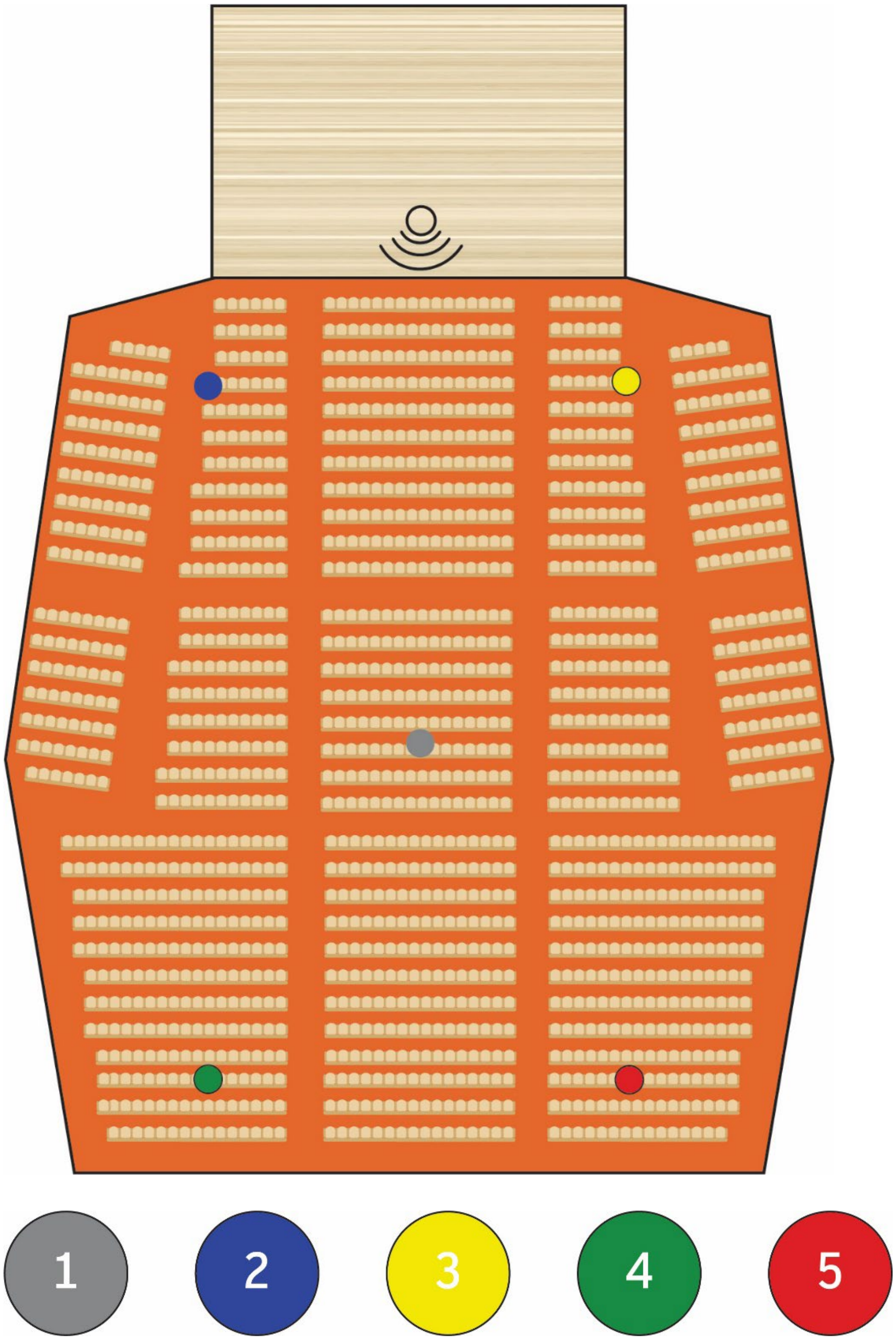

Figure 12 - Hall 2-point response layout.

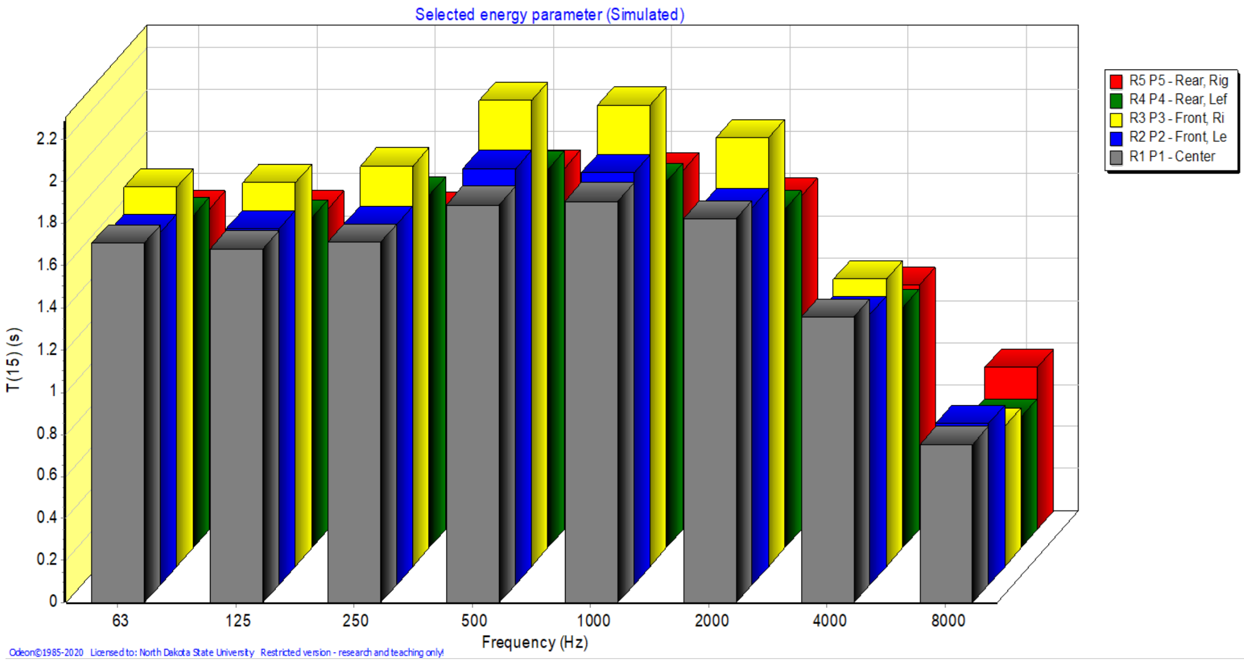

Figure 13 - Hall 2 T (15) results from Odeon.

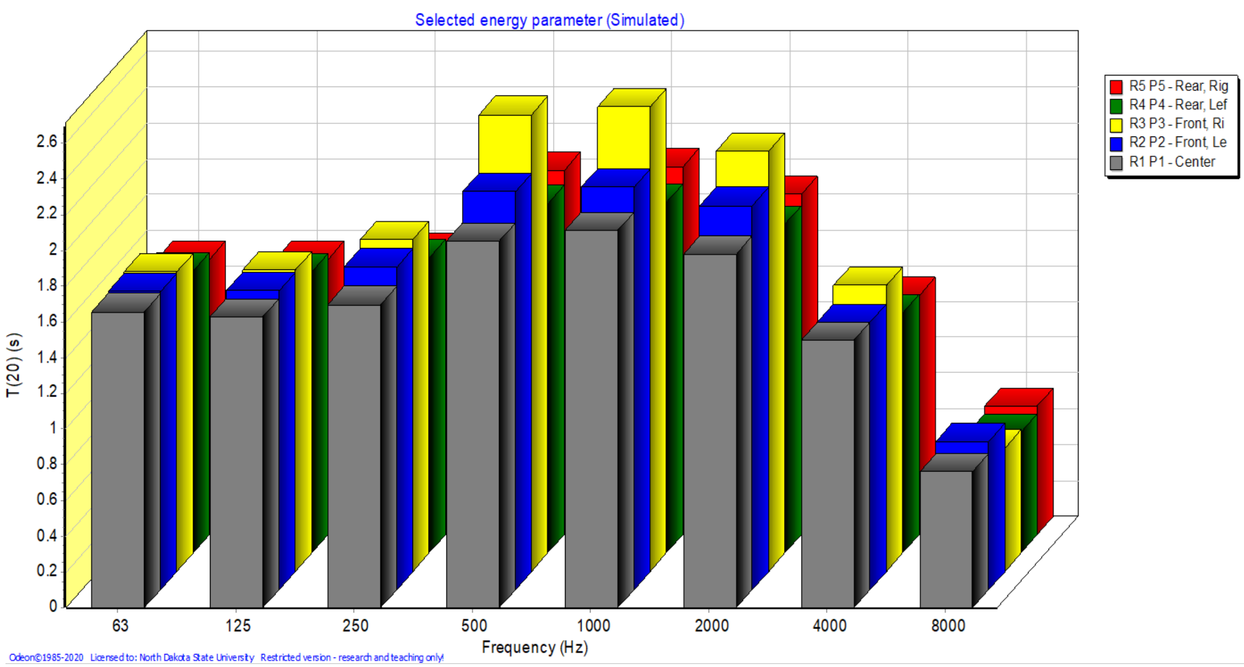

Figure 14 - Hall 2 T (20) results from Odeon.

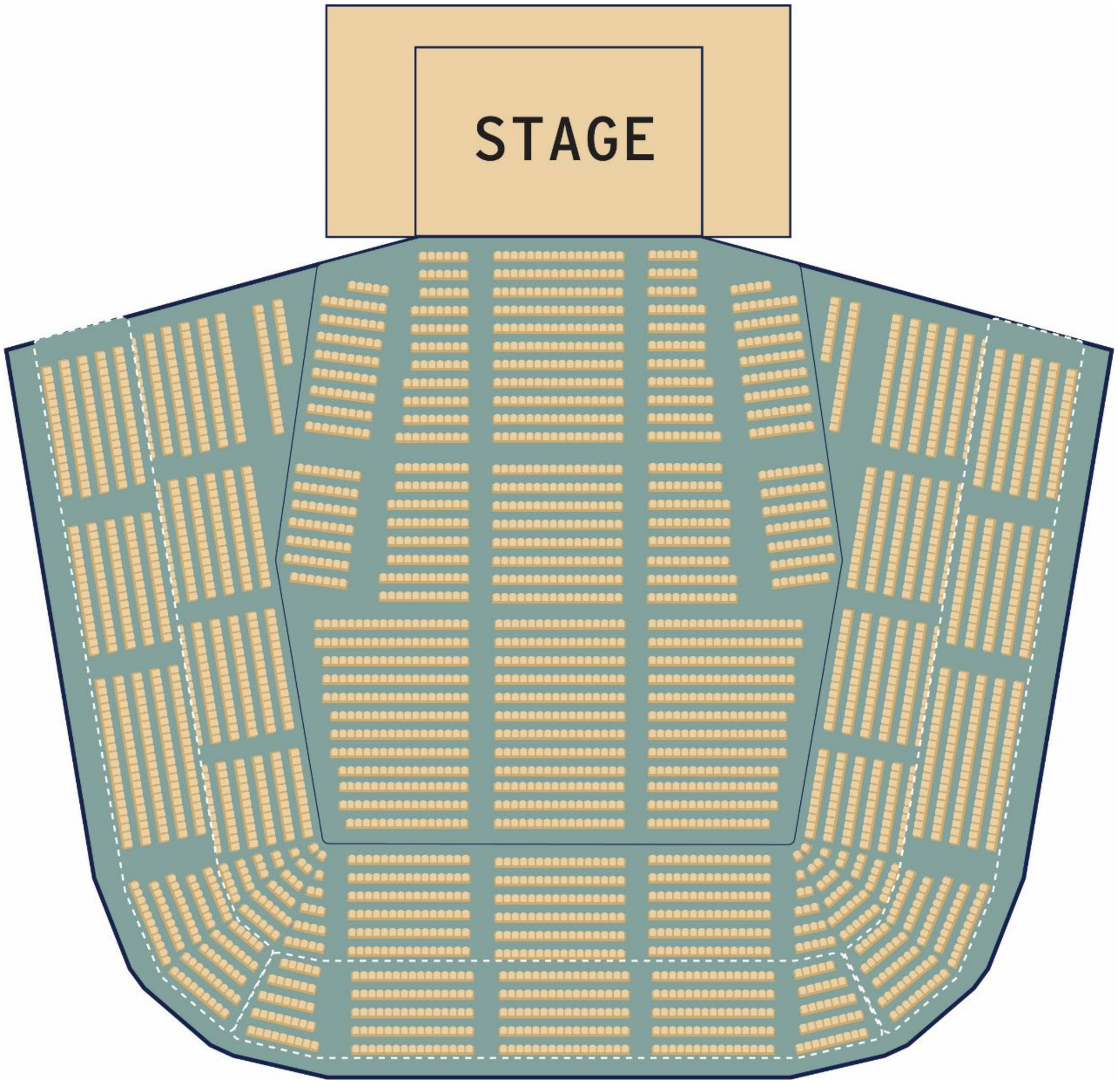

Figure 15 - Hall 3 Seating Plan

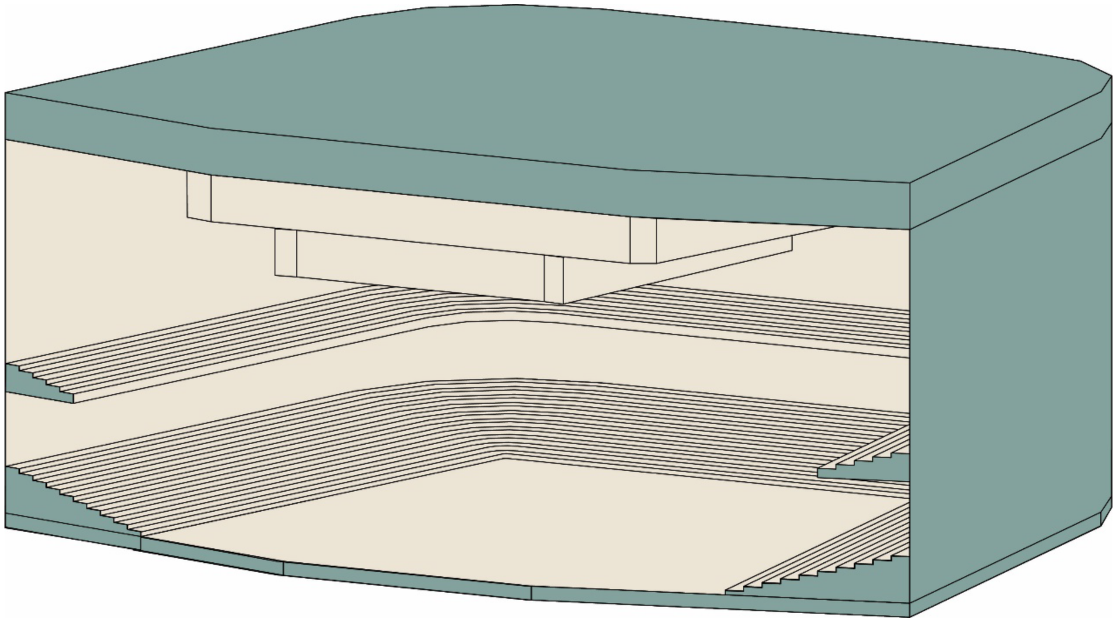

Figure 16 - Hall 3 Perspective View

Hall 3 has a capacity that ranges from 2350 to 2500 dependent on the stage configuration. Its intended uses include theatre, soloist performances, symphony, and orchestra. This is an amplified hall meaning performances will need electronic enhancements in order to reach the patrons appropriately.

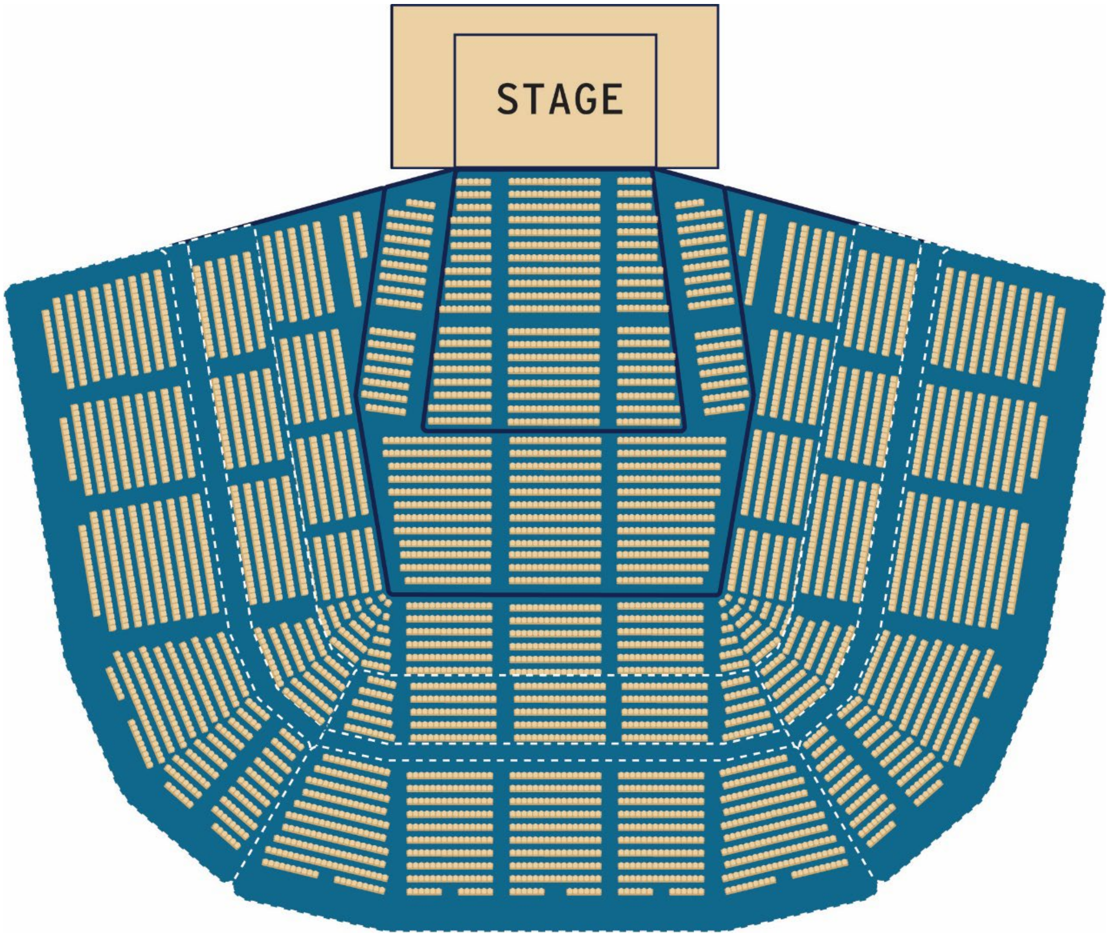

Figure 17 - Hall 4 Seating Plan

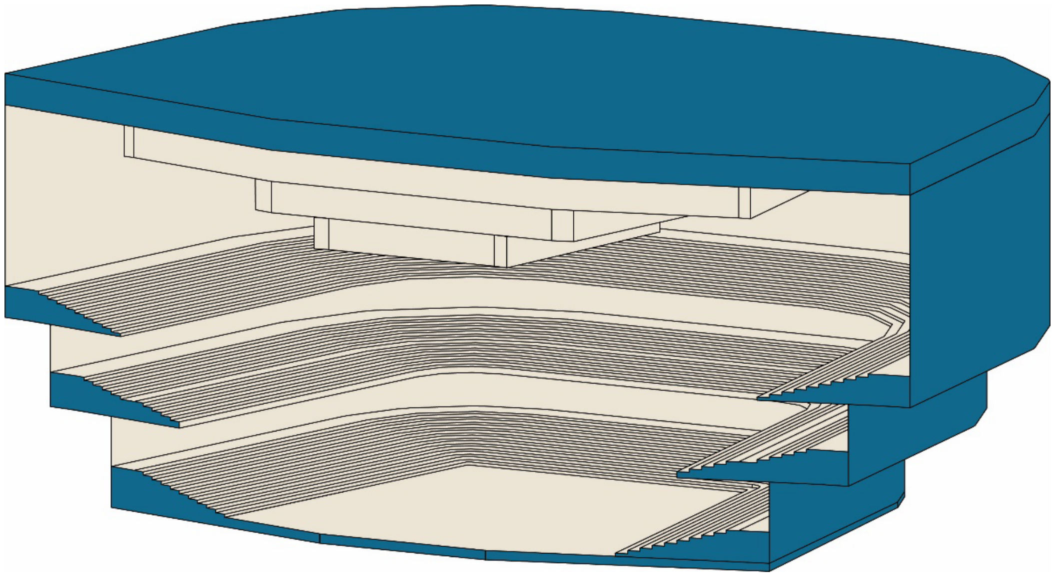

Figure 18 - Hall 4 Perspective View

Hall 4 has a capacity that ranges from 4700 to 4850 dependent on the stage configuration. Its intended uses include pop/rock concerts, theatre, soloists' performances. This is an amplified hall meaning performances will need electronic enhancements to reach the patrons appropriately.

4.4 Conclusions

Moving forward, the design concept could be realized in a more practical manner. Detailing the working pieces and structure to see how realistic a project of this nature is. The concept could also be taken in a mobile context seeing how a specific hall could be transported and constructed for tours and events. The morphing concept could be applied to almost any space that you want to get more utilization from, and fitted to users needs.

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APPENDIX

2nd year

Architecture Studio Space, Boathouse - Fall: 2020 - Charlotte Grueb

Marfa Community Project, DT Fargo Mixed Use - Spring: 2021 – Emily Gou

3rd year

Arabic Cultural Center, DT Fargo Mixed use - Fall: 2021 – Paul Gleye

Native American Cultural Center, FM veteran memorial - Spring: 2022 – Ronald Ramsey

4th year

The Edge - Mixed Used - Fall: 2022 - Amar Hussin

Marvin Windows Home, West Fargo Downton Master Plan - Spring: 2023 - Paul Gleye

5th year

Versatile Venue - Fall: 2023 - Ganapathy Mahalingam