



THE DESIGN AND RENOVATION OF A SMALL MULTI-PURPOSE HALL

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Resumo

A reabilitação do Cineteatro Narciso Ferreira, localizado em Riba de Ave, Vila Nova de Famalicão, Portugal, constitui um exemplo representativo das necessidades e compromissos envolvidos no desenho e projeto de pequenas salas de espetáculos para exploração das comunidades locais. Considerando o modelo de operação e os objetivos estabelecidos pelo município, o espaço foi renovado de forma a que pudesse acolher confortavelmente um programa extremamente variado.

Neste estudo de caso, são discutidos os principais desafios encontrados na introdução da versatilidade acústica necessária, mediante o cumprimento do orçamento estabelecido. São também apresentados os resultados da avaliação acústica final de conclusão de obra, que permitiram validar os requisitos de projeto previamente definidos. Para além dos parâmetros acústicos de referência, são também apresentadas visualizações tridimensionais da resposta impulsiva da sala.

Palavras-chave: acústica variável, sala multifuncional, acústica de salas, resposta impulsiva 3D.

Abstract

The renovation of Cineteatro Narciso Ferreira, located at Riba de Ave (North Portugal) is a representative example of the needs and choices that have to be considered when design a performance venue for a local community. Given its purpose and operation model, thoroughly defined by the municipality, a small multipurpose hall has been designed to ensure a wide variety of performances could excel.

For this case study, the challenges and options taken to introduce acoustic variability but still meet the budget set will be discussed. The compliance with the initial design targets will be presented given the results obtained during the final commissioning stage, that include not only the determination of benchmark parameters as well as 3D acoustic impulse response visualization.

Keywords: variable acoustics, multipurpose hall, room acoustics, 3D acoustic impulse response.

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1 Introduction

The design and renovation of small multipurpose halls presents unique challenges and opportunities for acoustic optimization. Such venues are crucial for local communities, providing spaces for a wide range of events, from theatrical performances and concerts to lectures and community gatherings. The Cineteatro Narciso Ferreira, a small theater located in Riba de Ave, North Portugal, underwent a comprehensive renovation aimed at enhancing its acoustic performance and suitability for its diverse program.

Acoustic design in small halls requires careful consideration of several factors to achieve a balance between versatility and performance quality. Unlike larger venues, where the room volume can aid in sound diffusion and absorption, smaller spaces can suffer from issues like inadequate loudness, poor sound distribution, and insufficient reverberation control, particularly at low frequencies. Key considerations in the acoustic design of multipurpose halls include the control of Reverberation Time (RT), the distribution of early and late reflections, and the integration of variable acoustic solutions to adapt the space to different events. The reverberation time is particularly crucial, as it influences speech intelligibility and musical clarity [1-2].

This particular theatre renovation included the installation of a retractable seating system, perforated fascia panels, additional stage and side wall curtains, and flexible bass absorbers. These elements were designed to provide an adaptable acoustic environment that could be adjusted to suit various types of performances. The use of advanced measurement and analysis tools, such as the IRIS system by Marshall Day Acoustics, allowed for a precise assessment of the overall result and a detailed comparison between each of the available room acoustic configurations.

This paper presents a case study that highlights the importance of acoustic flexibility in small performance spaces and demonstrates how thoughtful design can enhance the functionality and versatility of such venues.

2 General Characteristics

2.1 Large halls vs small halls

Despite often presenting considerably different infrastructures, smaller and larger halls are prompted to house similar programs, meaning both will be used for large size orchestral ensembles, for example. Therefore, while a large hall might be designed in search for some of the intimacy of a smaller room, the success of lower seat-count performance spaces is often associated with its ability to sound “larger”, which is in part related to a large orchestra being “not too loud” and whilst preserving adequate reverberation and width characteristics [2].

When comparing the acoustics of large and small venues, it has been documented that most of the relevant acoustic attributes, such as the level of the direct sound, level and density of early reflections, level of the reverberant field, total sounds strength, among others, show greater values for the lower occupancy halls. This means that, apart from overly absorptive rooms, smaller venues tend to sound louder than larger equivalents [3].

2.2 Small hall design recommendations

Due to their inherent multifunctionality and considering the previously described context surrounding the acoustic challenges of small performance halls, it is important to acknowledge the singularities involved in such designs, which require adapting our references and focusing on otherwise neglected features. For instance, although this sort of venue is typically designed for acoustic acts, they are also equipped with PA systems for amplified performances, which requires attention to details such as the maximum SPL or the room's response at low frequencies.

Table 1 summarizes some of the major design guidelines recommended for small halls, regarding volumetric, stage and acoustic conditions [1-2].

Table 1 – Design guidelines for small performance halls

Volume	Typically, should range between 10-14 m ³ /seat. However, it is also relevant to define the volume as function of the number of performers/musicians. Later designs suggest 100 m ³ /musician, meaning the current hall is better suited for small chamber orchestras. Varying the room's volume is effective in adapting its response, yet extremely difficult to accommodate, especially in community venues and renovation projects.
Stage	Stage draping should be adaptable and removeable to allow for larger reflective surface areas. Overhead removeable reflectors should be considered for acoustic concerts. For smaller acoustic ensembles, the side and back stage areas should be closed off by reflective elements.
Variable acoustics	Variable acoustic conditions are essential for multipurpose halls. The two mainly used strategies rely on variable absorption and variable volume. Curtains are a cost-effective solution for covering large surface areas, making it easier to achieve audible changes in the room's acoustic response. Placement of variable acoustics solutions is most efficient: around the stage, across the room, back wall and side walls. Elements of efficient low frequency control must also be considered.

2.3 Cineteatro Narciso Ferreira

The present case study focuses on the renovation of a small theatre in the north of Portugal, Cineteatro Narciso Ferreira. The general dimensions and characteristics of the venue are detailed in the table below.

Table 2 – Dimensions and general information about the venue

Audience Length	Width	Audience Max. Height	Audience Min Height
27,0 m	11,5 m	12,0 m	9,5 m
Stage Length	Stage Height	Volume	Seats
27,0 m	9,0 m	3105 m ³	168



Figure 1 – Cineteatro Narciso Ferreira

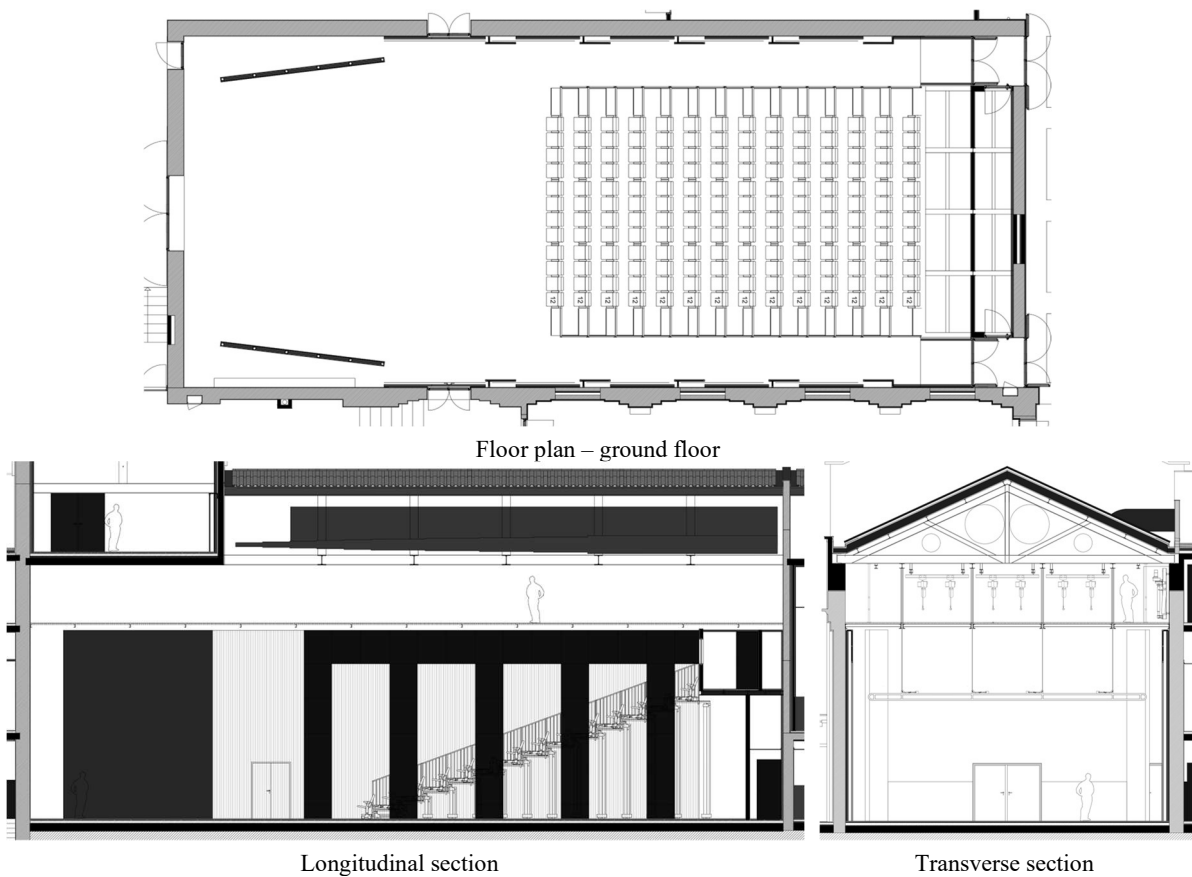


Figure 2 – Building floor plan and sections

To ensure the hall was suited for a wide variety of performances, as described and according to the client's and community's interest, several acoustic features were included in the refurbish process.

First and foremost, a retractable seating system was installed, to enable the use of the whole floorplan, for standing audience events, for example. The fascia panels of the retractable system were perforated with 20% of minimum open area so it can still contribute with significant sound absorption, even when the audience seats are enclosed on the back of the room. One of the main purposes of preserving the sound absorption from the retractable seats is to attenuate the difference in equivalent sound absorption area of the room with and without the seating structure.



Figure 3 – Unfolded seating system (left) perforated fascia panels (right)

Furthermore, besides the traditional stage draping, additional curtains were installed over the solid wood diffuser areas on both side walls.



Figure 4 – Side wall diffuser panels without (left) and with curtains (right)

Although curtains may offer a cost-effective variable acoustic solution for mid and high frequencies, the fact is they often lack the sufficient performance at low frequencies [3]. Therefore, a couple of Flex Acoustic's aQflex flexible bass absorbers were installed across the length of the room.



Figure 5 – aQflex bass absorbers (inflated)

All of the mentioned features were carefully sourced, designed and implemented to attend to the varying acoustical needs of such a multipurpose space.

3 Methodology

3.1 Measurement setup

To assess the baseline acoustic behavior of the venue and study the effects of its variable acoustics features, the room's impulse response was measured in multiple locations, for every available room configuration. These tests were conducted using IRIS, an integrated hardware and software tool for capturing and analyzing room impulse responses in 3D, developed by Marshall Day Acoustics.

The measurement setup was comprised by the following main equipment:

- Dodecahedron loudspeaker and corresponding amplifier module;
- Windows laptop with IRIS software by Marshall Day Acoustics;
- Core Sound TetraMic microphone array;
- MOTU 4pre USB audio interface (with IRIS CBM connection box).



Figure 6 – Measurement equipment: TetraMic (left), dodecahedron loudspeaker (middle), IRIS kit (right)

Apart from validating the project requirements regarding the acoustic response of the hall, the commissioning stage measurements were conducted to investigate the real impact of the different variable acoustics solutions that were implemented. Therefore, the present analysis will focus on the measured reverberation times for the 63-8.000 Hz octave bands to assess the extent of the room's adaptative characteristics and to infer its suitability to different performative content. Additionally, taking advantage of the measurement system's capabilities, a spatial analysis of the impulse response took place to evaluate the geometric influence of the variable acoustic elements in the sound field that reaches the receivers [4].

3.2 Measurement procedure

The measurements were carried out for each of the room configurations described according to Table 3. For every configuration the same 2 source and 6 receiver position were considered and every source-receiver pair was measured. The height difference of the receiver positions for the room configurations with and without the seated audience area were not considered for the purposes of the current analysis.

A sweep signal of 30 seconds was used for the data acquisition with a set gain staging in order to not saturate the system or the loudspeaker. The microphone and sound source were positioned at 1,2 and 1,5 meters height, respectively, and at least 3 meters away of any wall surface.

Table 3 – Room configurations

Configuration	Curtains		Retractable seats	Bass absorbers
	Lateral	Stage		
1	On	On	Off	On
2	Off	On	Off	On
3	Off	Off	Off	On
4	Off	On	On	On
5	On	On	On	On
6	On	On	On	Off
7	Off	On	On	Off
8	Off	On	Off	Off
9	On	On	Off	Off



Figure 7 – Receiver (green) and source (red) positions

4 Results

The average reverberation time measured of all source-receiver combinations, for both source positions, and for all room configurations are showed in Figure 8.

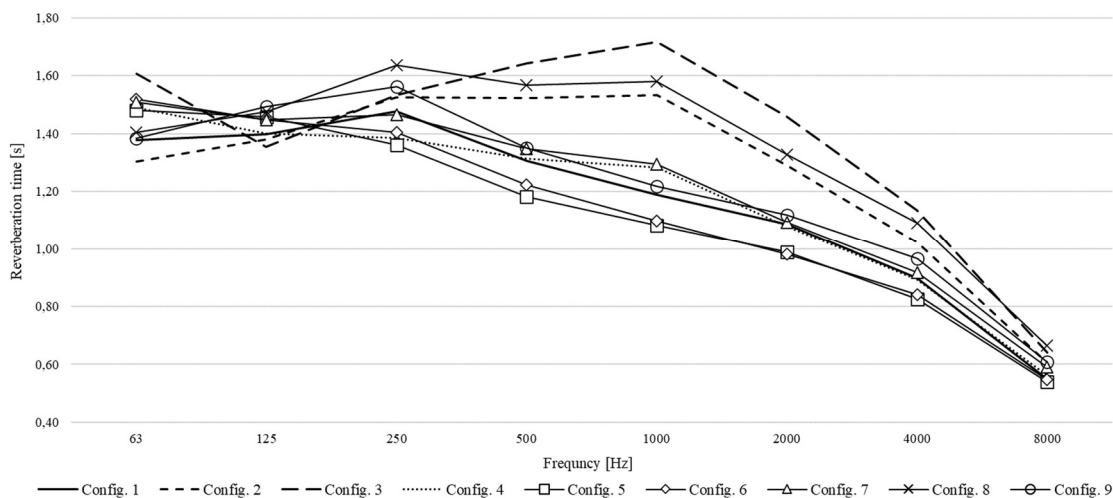


Figure 8 – Average reverberation time for each room configuration, in octave frequency bands

According to the operational needs and standards of the venue and although the stage draping is effectively removeable and can be repositioned, the admitted baseline configuration is the one described in Config. 8. Therefore, although the room was measured without the stage curtains (Config. 3), the reverberation time values obtain for Config. 8 will stand as the reference point for the room's most lively response.

A first quick glance at the Reverberation Time (RT) plots reveals the objective of displaying very different room acoustics responses has been achieved. The different reverberation times (magnitude and spectrum profile) provided by each configuration allow for a large number musical programs and can also create the inspirational and creative conditions for some site-specific creations.

Furthermore, if the RT plot analysis is restricted to the 500, 1.000 and 2.000 Hz octave bands, it becomes clear that the available configurations supply the room with 3 main reverberation characteristics: the liveliest setup is provided by Config. 2 and Config 8, as showed previously; the least reverberant response is set by Config. 5 and Config. 6; all the remaining configurations stablish an intermediate level, with slight character variations among them.

On the other hand, it is observed that the side curtains and the seats have greater impact on the overall room response than the low frequency absorbers, as the later cover a much smaller area and have been designed to act mostly on frequencies below 1.000 Hz. Figure 9 shows the resulting RT reduction from only inflating the aQflex tubes (Config. 2), when compared to the reference configuration (Config. 8).

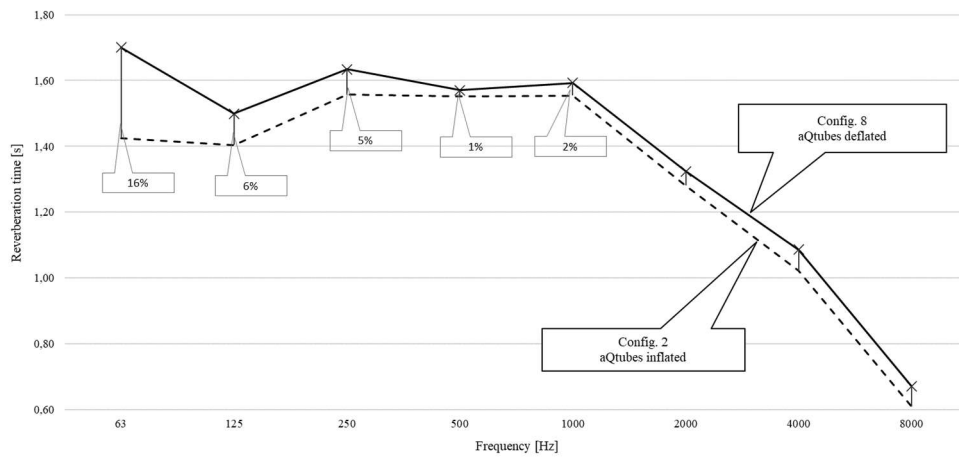


Figure 9 – Average reverberation time with (Config. 2) and without (Config. 8) the low frequency absorption

Figure 10 shows that, as expected, the configurations where all curtains were on and the audience seating was unfolded (Config.5 and Config. 6), where the ones who achieved lower reverberation times, with minimal differences between the two.

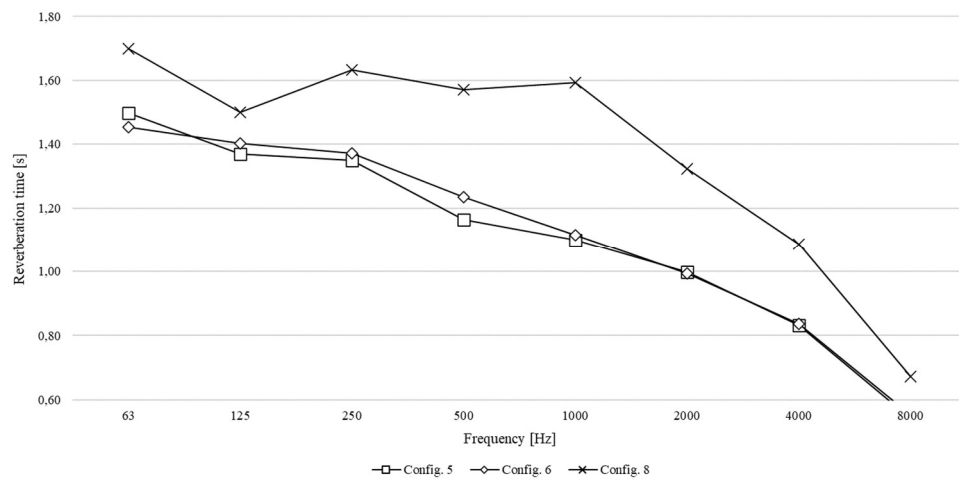


Figure 10 – Average reverberation time of the room with side curtains and unfolded seats (Config. 5 and 6) compared to the reference configuration (Config. 8) without any of these features. Values refer to the measurements with the sourced positioned on S1.

For the audience experience, both the temporal and spatial characteristics of the sound field are relevant. To evaluate them it has been well proven that one of the most important spatial acoustic parameters, on which the variable acoustics options have a more significant impact, is the Lateral Fraction (LF) [5-6]. Figure 11 shows the LF values measured for a particular source-receiver pair, together with the corresponding intensity vector plot, for Config. 8 (lateral curtains off) and Config. 9 (lateral curtains on), at 1.000 Hz.

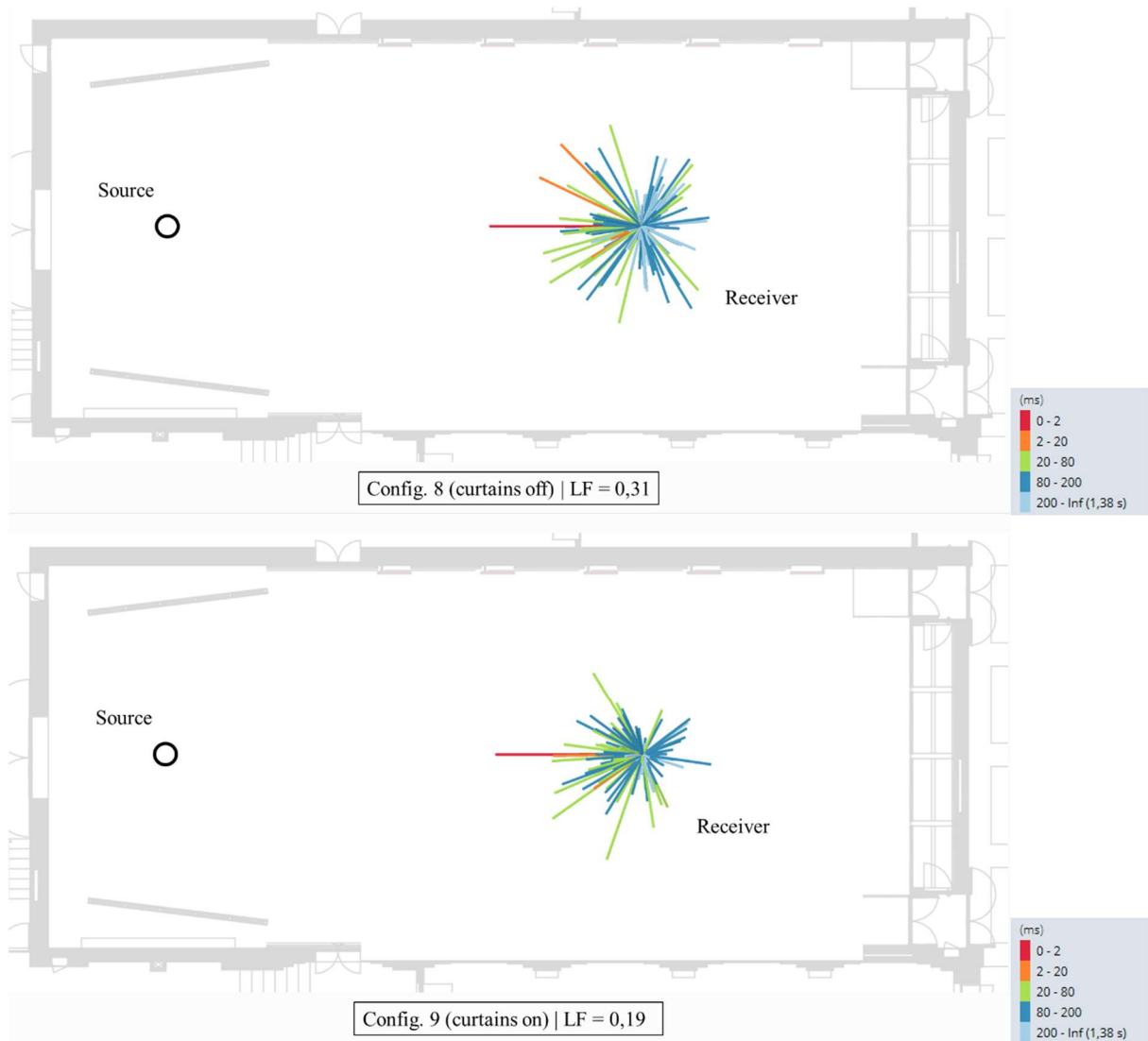


Figure 11 – Intensity vector plot at 1.000 Hz and LF values for Config. 8 and Config. 9 for a given source-receiver pair

The lower LF value for Config. 9 is corroborated by the differences shown between the intensity vector plots. The plots show that later reflections (blue) reach the receiver with significantly less energy for Config. 9, two strong early reflections (orange) from the right-side wall are eliminated by the curtains, and that the density of lateral and back wall reflections is largely reduced in comparison to the sound field coming directly from the front of the room.

5 Conclusions

The renovation of Cineteatro Narciso Ferreira demonstrates the feasibility and effectiveness of introducing variable acoustic solutions in small multipurpose halls. The project successfully addressed the complex acoustic requirements of a venue intended for diverse performances, within the constraints of a limited budget.

The implementation of variable acoustic features, including a retractable seating system, stage and side wall curtains, and flexible bass absorbers, allowed the hall to achieve distinct acoustic environments, suitable for different types of performances, thus providing 3 main reverberation characters to serve the venue's program. The comprehensive measurement and analysis process, facilitated by the IRIS system, provided valuable insights into the time and spatial acoustic performance of the room in different configurations.

The study showed that the side curtains and the seating system had a more significant impact on the overall room response compared to the low-frequency absorbers, which primarily affected frequencies below 1000 Hz. This highlights the importance of strategic and complementary placement and design of acoustic elements to achieve desired outcomes, especially in halls equipped with Public Address (PA) electroacoustic systems.

The analysis of spatial acoustic parameters, such as Lateral Fraction (LF), provided deeper insights into the spatial distribution of sound energy and its effect on listener perception.

This case study aimed to provide useful insights for the design and renovation of small multipurpose halls, underscoring the importance of flexibility in acoustic treatment options in addressing the unique challenges of such spaces.

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