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The acoustical quality of rooms for music based on their architectural typologies

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Abstract

The acoustical quality of an auditorium for music is a complex cultural subject that involves, at least, the physics of waves, the auditory perception, the musical use of the space and the listeners' individual preferences. The scientific analysis of those questions requires the examination of the complex correspondence between the acoustical fields and the music perception of them.
The main objective of this paper is to develop a methodology of acoustical analysis and design, which allows us to predict some aspects of the final acoustical quality of a hall based on its basic architectural shapes.
From the selected acoustical data, four main architectural typologies were established as canonical shapes: shoebox, fan, vineyard and horseshoe. All of them have their own and particular acoustical behavior.
The analysis carried out in several auditoriums and theatres within the Republic of Argentina allows us to conclude that the acoustic quality of a hall for music can be inferred from its architectural basic typology, if certain general conditions are met. On the other hand, it is possible to explain the behavior of some non-traditional acoustic fields by applying an analysis that combines various architectural typologies.

Keywords: acoustic quality, auditoriums, Argentina.

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1 Introduction

The analysis and acoustical design of rooms for music have, for a while now, required a group of tools suitable to be applied by architects in the preliminary sketch phase. Currently there are a few principles they can use when conceiving an auditorium or a theatre and they are guided by the mimesis of existing halls or by their aesthetic preferences and intuition. Consultation with a specialist in the field does not solve the problem either since, beyond the indication of volumes and materials, the consultant waits for the architect to decide the general layout to start with the calculations. On the other hand, the specialized software packages need to be fed since the beginning with the preliminary sketches already sorted out. The main theme of this paper raises the possibility of anticipating the final acoustical outcome as from the basic architectural shape. The typological analysis will allow them to achieve a satisfactory acoustical result without resorting necessarily to the traditional shapes.

2 General Framework

A hall for music is defined by its acoustical quality, which is obtained as from the aesthetic value judgements made by the audience based on what they hear, their music expectations, their personal likes and what they consider correct for that time. As with any perceptual evaluation, it depends and is defined to a great extent by the music culture of the group of people consulted, which varies over time and place taken into consideration. It also varies from individual to individual; what is more, the same individual can change their evaluation of acoustical quality of the same room in different moments.

The acoustical quality also depends on the physical behaviour of the sound waves in the room. The main topic of scientific study of halls acoustics is precisely the complex, multidimensional and changing link between the physical fields and the perception of these fields.

The first historical attempt to relate a physical aspect of a space with what is heard inside it was carried out by Wallace Sabine in the late 19th century. Sabine defined the Reverberation Time and its calculation binds the size of the room and the amount of absorbent acoustical material inside it to the first and simple conception of perceptual quality. It was during many years and it still partly is the main variable to consider in the acoustical project of a hall.

Other physical aspects that define the acoustics of a hall are the architectural typology and the scaling factor. The acoustical behaviour of a music room, and therefore, its sound quality are determined to a great extent by the Reverberation Time, the size and shape.

3 Relationship between architectural characteristics and acoustical behaviour

The analysis and case studies performed lead to the conclusion that the acoustical quality of a music hall can be inferred as from its basic architectural shape if certain conditions are met. In the first part, there is the list of acoustical characteristics to be expected in a space depending on each architectural typology. Following, we analyse certain halls that do not behave acoustically as determined by the basic architectural typology.

3.1 Remarkable acoustical characteristics of the different architectural typologies

3.1.1 Shoebox

The typology of the shoebox was standardised in the 19th century for architectural reasons and not acoustical ones. This framework remained a standard typology until the First World War and had a deep revision in the 1980’s.

The most important acoustical characteristics of these types of halls are:

- The Reverberation Time is approximately of 2 s for mid-frequencies.
- There is much Fullness of sound coming from every direction –the listener feels immersed in reverberating sound-.
- The Clarity has high values.
- The room has a broad dynamic range and responds instantly before the minimum change in the articulation of the orchestra.
- In general, it shows high evenness in every location.
- Among the instruments, there is a good spectral and loudness balance. The assembly among musicians is very good.

In the shoebox, the listener is reached by the direct signal coming from the acoustical source – the orchestra- and also many signals deriving from the reflections in the walls of the hall. They feel enveloped by sound and that the source shares the same acoustical space. The acoustical quality of the hall improves if a considerable number of early lateral reflections occur between the arrival of the direct sound and 80 ms.

One of the most important factors when assessing the acoustical quality of a music hall is the feeling of envelopment in the room –the acoustical field has a high Spatiality Factor value -.

According to many studies, the shape of a hall for symphonic music should prioritize lateral reflections. This is one of the reasons why it is preferred rectangular floor halls over other possible shapes.

3.1.2 Fan

The possibilities offered by the new technologies and building materials after the First World War allowed the architects to change the traditional typologies, dimensionally limited, mainly to increase the number of people. In some cases, the lateral walls were opened into a spatula or fan-shaped floor. The rear wall in these auditoriums often takes a curve shape and the ceilings frequently progress to an equipotential or isophonic development, which ensures a homogenous distribution of the acoustical energy (method of Lyon).

In a hall with a fan-shaped floor, the direct sound reaches the audience easily, but the sound coming from the reflections of the lateral walls goes towards the back. When there is only frontal sound coming from the orchestra, the acoustical source is perceived at the front, far and separated from the listener. Having little lateral energy, the audience does not receive the necessary spatial information so as to feel surrounded by sound.

In a fan:

- The Reverberation Time is, in general, low because the volume is reduced when the ceiling height is lowered and the area of absorption of the audience is increased. On the contrary, the best halls of this typology are those which achieve a high value of RT.
- There is a very low value of Clarity and the details of the music get lost.
- The assembling on stage is difficult since the sound does not come back to the sources and heads towards the back of the hall.
- Prominent echoes can appear. The acoustical signals arriving to the curve wall at the back of the hall and to the front of the balcony come back to the stage with a lot of energy.

According to Beranek, a fan-shaped hall can be effective for audiences smaller than 800 people or, under certain circumstances, over 3200 people. In a small fan-like hall there are no lateral reflections that contribute and/or alter the direct sound which gives it a relative definition that could be considered acoustically good (Beranek, 2014).

3.1.3 Arena

The typology of arena or vineyard appeared in the early 1960’s and it offers, for symphonic music, a variation to the geometry of the classic shoebox.

The feature that characterizes arenas is the location of the stage near the center of the hall and in a lower level to that of the audience, which is located on raised terraces.

In a vineyard hall it is difficult to produce a great number of lateral reflections since the audience is located around the stage and the walls are low and far from the instruments. Therefore, the sequence of early reflections present in rectangular halls is lost. One technique to compensate this deficiency consists in locating the audience in blocks whose fronts reflect the lateral energy towards the audience near the stage and towards other blocks.

The most relevant acoustical characteristics of vineyards are:

- They can hold a great deal of people.
- The Reverberation Time can reach values similar to the optimal ones for symphonic music.
- They are not homogeneous halls and allow many different hearing conditions.
- In the area of the audience in front of the orchestra, the sound is clear, balanced and with a timber definition that envelops completely the audience –there are sectors of the audience in front of the orchestra where the music quality can be as high as the one in the shoebox-.
- In the seats at the back of the stage, the sound is completely different, with instrumental balance almost inverted.
- Certain seats, where the audience can appreciate the body language of the orchestra conductor, are preferred for visual reasons.

Contrary to what is claimed by a great deal of the specialized literature, the lack of homogeneity of the acoustic field is not necessarily a drawback. In a vineyard it is possible to have an answer to particular preferences choosing the seats that are better suited for every type of listener.

3.1.4 Horseshoe

The acoustics in opera theatres has been almost the same from Monteverdi to the present days. Opera houses, created on a trial and error basis, have become the most efficient model for the genre and constitute the most remarkable case of acoustical stability in Western history.

Its main features are:

- The RT reaches a value close to 1.5 s regardless of the size and seating capacity. This RT value is appropriate for an opera house to fulfill its two main acoustical objectives: music continuity and speech intelligibility.
- They include two big coupled acoustical volumes: the stage and the hall.
- The stalls must meet every spectator’s demand for a maximum visual angle in accordance with the back of the stage and the proscenium opening.
- The acoustical balance between the orchestra musicians in the pit and the singers on the stage is very good –in good horseshoe halls, the sources located in the pit produce levels 3 dB and 5 dB lower than those on stage-.
- It has high Clarity values.

3.2 Halls that do not behave acoustically according to their architectural typology

Despite the previous enumeration of the canonical characteristics for every type of hall, there exist spaces where the acoustical behavior is not like the standard ones, many times decreasing the expected acoustical quality and others, less frequently, increasing it. Here we will analyze briefly some of these special cases.

3.2.1 Shoebox

Philharmonic Hall

In 1962, Beranek decided to take the theory of Sabine to the limit and designed, based on his theory which aims at minimizing the Delay of the First Significant Reflection that gets to the listener (ITDG), a shoebox hall with a floor a little modified with two upper levels and a cloud of suspended adjustable panels.

In the acoustical result, the sound was flat and too bright, without spatial feeling, without good responses in low frequencies. The musicians could not hear one another and there were echoes on the stage and in some seats at the front. Nothing could be further from the excellent shoebox halls of the 19th century, which theoretically had been the basis of their design.

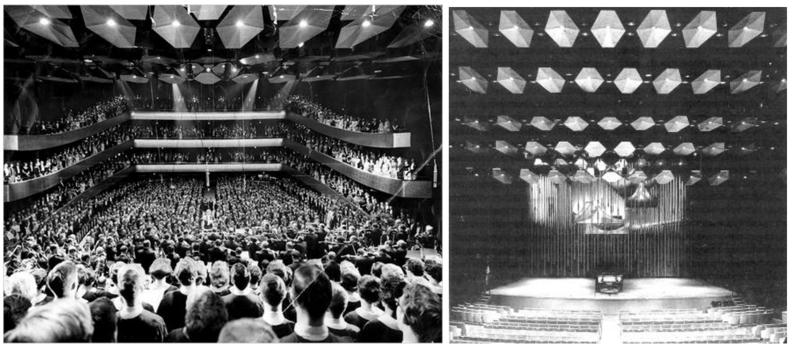

Figure 1. Pictures of the interior of the hall.[1]

The reasons for this behavior were multiple. Among them:

- A low value was the Reason for Low Frequencies. The ceiling returned the energy reflected by the panels in the range of 125 Hz to 250 Hz 11dB below the one reaching the bands of 500 Hz and 1,000 Hz. The dimensions of the panels, an insufficient size, did not let sounds below 300 Hz be reflected appropriately. In the perceptual level, there was difficulty to hear the instruments of the lower part of the spectrum of the orchestra.

- The sound waves of low frequency diffracted in the successive rows of the backrests of the seats in the stalls increasing the loss in the bass part of the spectrum.

- The interior surfaces did not give an adequate acoustical diffusion.

[1] Taken from http://lincolncenter.tumblr.com/post/62059816319/this-date-in-lincoln-center-history-philharmonic (left) -Picture: New York Times-. Access: January 2015.

http://www.nycago.org/Organs/NYC/html/AveryFisherHall.html (right). Access: January 2015.

- The rear wall of the stage, absorbent, increased the difficulty in instrumental performances on the stage. The Support Factor and the Level of Early Assembly were very low.

The hall had a roughly rectangular floor, a ceiling with an almost constant height, and satisfied the conditions of the theory of Sabine. However, the final acoustical result did not meet the expectations promised by its architectural typology.

3.2.2 Fan

Tanglewood

Despite having a fan-shaped floor, the hall of Tanglewood in Massachusetts is a space acoustically successful (Beranek, 2014). With an original design of reflective upper panels, Beranek managed to solve optimally the acoustical disadvantages typical of its typology.

Although it is a hall with a huge seating capacity -5,121 listeners- and its floor is not, a priori, very suitable for music, the acoustical design chosen places it among the best halls in the USA according to the specialized critic.

Figure 2. Picture of the hall.[2]

[2] Taken from http://www.berkshireeagle.com/ci_23507742/tanglewoods-koussevitzky-music-shed-turns-75. Access: January 2015.

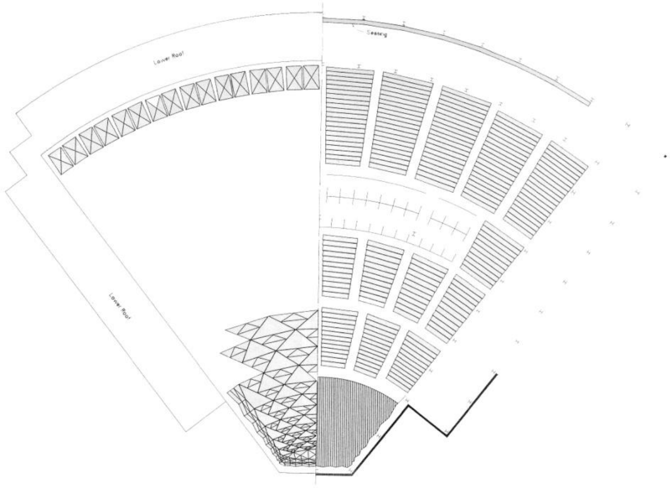

Figure 2. Floor of the hall. Taken from Leo Beranek (1996). "Concert and opera halls. How they sound".

3.2.3 Horseshoe

Teatro Municipal Coliseo Podestá. La Plata, Province of Buenos Aires

The Teatro Municipal *Coliseo Podestá* inaugurated in 1886 apparently belongs to the typology of traditional Italian theatre. However, since it originally had to be adjusted for circus performances, the stands were positioned in a horseshoe fashion which surrounded a circular riding arena. In 1913, the building was remodeled and turned into a drama theatre.

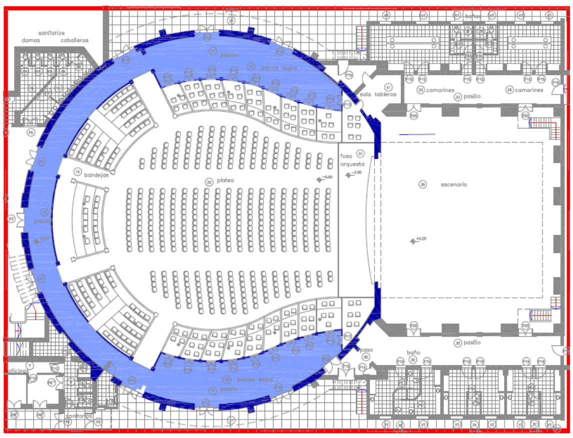

Figure 5. Stall floor and lower box seats where one can see the two delimiting perimeter envelopes and the circulation aisle.

The acoustical consequences of the shape of the envelope, before the 1986 restoration, were significant. Among them are:

- The hall had two distinct and audible slopes of decay. The first slope was the central volume with a value of Reverberation Time to mid-frequencies near 1 s. The second slope, which was generated in the coupled volumes of the circulation corridors/aisles that surrounded the main hall, derived from much lower acoustic levels, determined a RT near 2 s.
- There was a big spatial spread of Reverberation Times values in the stalls.
- The two perimeter envelopes of the hall generated acoustic focalizations and echoes in the stage area.
- The relationship EDT/RT did not follow the standard curve typical of a horseshoe hall according to the distance from the source.

4 Conclusions

The main hypothesis that suggests determining the acoustic quality of a music hall from its basic architectural shape is fulfilled in most of the analyzed cases. It is possible to determine a set of values for relevant acoustic parameters depending on the chosen typology, as long as other factors such as acoustic absorption of the interior surfaces are within the standard limits and there are no evident defects such as echoes, distortions or spectral coloration.

Apparently, some halls do not behave acoustically in accordance with their architectural typology. However, it has been proved that some cases can be understood moving away from the corresponding standard model. Many times an almost indiscernible difference can have relevant acoustic consequences.

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