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## Introduction

The Vatroslav Lisinski Concert Hall in Zagreb (opened 1973) remains an influential reference for medium-sized “shoebox” auditoria. The hall hosts symphonic music, amplified events, and conferences.

Beyond the documentation of the current acoustic signature, the assessment can be exploited to compare the results with those from other modern shoebox halls. Also, adjustments can be identified any targeted to optimize clarity for spoken events while preserving the warmth valued for symphonic music.

### Historical value and architectural features

The Concert Hall was designed by a group of architects, Marijan Haberle, Minka Jurković, and Tanja Zdrovák, and construction started in 1961. The hall is named after Vatroslav Lisinski, the composer of the first Croatian opera. It has a large stage, Walcker concert organs, and a big indoor projection screen. Its internal space is shown in Figure 1.

A single-span steel arch truss, rising about one-sixth of the span, bridges the entire width and leaves the interior free of columns. Inside this envelope, the audience chamber is an irregular fan.



Figure 1: Internal view of Lisinski Concert Hall in Zagreb, Croatia.

Three hydraulic lifts in the forestage allow rapid conversion between symphonic, operatic, and conference modes, while an independent concrete substructure limits structure-borne noise transmission to the hall.

Acoustic conditioning relies on several complementary measures like rough-surfaced hardwood paneling on the side walls and balustrade combines a field of plywood reflector blocks suspended below the roof and uniform diffusion. Over the years, the hall has gone through several renovations to improve its acoustics and technology. Figures show the plan and longitudinal section of the concert hall.

Description	Features
Type of plan layout	shoebox shape
Total capacity	1974
Main Hall axes	56.6 × 41.5 m
Stage dimension	25 × 9 m
Inclination of stalls	25%
Volume	42,000 m <sup>3</sup>

Table 1: the architectural features of the Lisinski

## Experiments

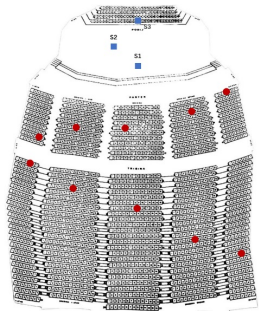


Figure 4: Positions of the measurement points

To evaluate the room response, an acoustic measurement campaign was conducted using the following equipment:

- Equalised omnidirectional loudspeaker Look Line
- Binaural dummy head – Neumann KU-100
- B-Format – Sennheiser Ambeo
- Omnidirectional microphone – Bruel&Kjaer
- 64-channel spherical array MH Acoustic em64 Eigenmike®

Three source positions were established in the stage. All sources were mounted at a height of 1.5 m above the floor. Receivers were placed at a height of 1.2 m, corresponding to the average height of a seated listener's ear. Illustrated in Figure 4 are the chosen source and receiver positions.



Figure 5: On-site photos of the sound source placements

The excitation signal emitted from each source was an exponential sine sweep (ESS) with a duration of 15 seconds from 40 Hz to 20 kHz. In Figure 5 positioning of the sound source on the stage. Measurements were conducted in an unoccupied hall, with the receiver moved to multiple locations throughout the main audience area, as schematically.

## Results

The acquired impulse responses (IRs) were processed and analysed to obtain acoustic parameters, that were derived following the methodology specified in ISO 3382-1. Results were averaged across all receiver positions, with the three plotted curves representing measurements from the three individual source positions.

Results in the frequency domain are between 125 Hz and 4 kHz.

### Reverberation time

EDT averages 1.5 s at 125 Hz and it climbs to about 2.2 s at 2 kHz before falling back to 1.8s at 4kHz. The T30 results follow a similar frequency profile starting from 1.8s at 250Hz and peaking at 2.2 s before decreasing at 4 kHz. Both EDT and T30 remain between 1.8 s and 2.2 s across the critical 500 Hz–2 kHz range, a window regarded as optimal for symphonic repertoire while still offering adequate clarity for amplified speech. The consistency across source locations confirms that the hall can accommodate diverse stage layouts without compromising reverberation control. EDT and T30 can be seen respectively in Figure 6 and 7.

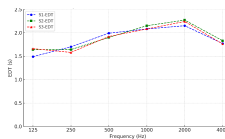


Figure 6: Results of Early Decay Time (EDT).

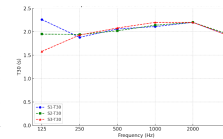


Figure 7: Results of Reverberation Time (T30).

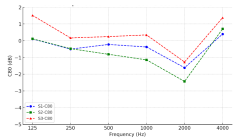


Figure 8: Results of Music clarity index (C80).

### Clarity indexes

Speech clarity (C50) is dominated by negative values throughout the spectrum, with the poorest value at 2 kHz and a modest recovery above 4 kHz. The choir-area source (S3) delivers the best result, staying on an average of -2dB. Although these values generally regarded as acceptable for unamplified speech.

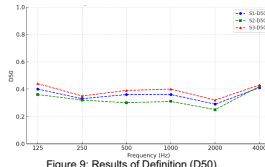


Figure 9: Results of Definition (D50).

Music clarity (C80) in Figure 8 follows a comparable pattern but shifts upward by roughly 2 dB. The choir source again performs best. All curves stay within the -2 dB to +2 dB interval that affords for symphonic repertoire. The close spacing of the three traces consistency with the room's symmetrical geometry and evenly distributed overhead reflectors.

### Definition

Figure 10 confirms that the speech definition index (D50) is stable across source locations and frequency between 0.25 and 0.44. The choir-area source (S3) is consistently the highest, but most values remain below the 0.50 target often cited for unamplified speech. Curve stay above the 0.30 threshold regarded as the lower limit for intelligibility, indicating that the hall offers uniform, moderate speech definition.

Figure 10: Results of Interaural Cross-Correlation (IACC).

### Inter-aural cross-correlation

Figure 11 shows that coherence falls from 0.95 at 125Hz to around 0.40 at 500 Hz. Across all octaves, the spread between sources is very low (under 0.07).

The mid- and high-frequency IACC values indicate sufficient decorrelation between the ears to support a clear sense of spaciousness, while the high coherence at low frequencies is typical of omnidirectional wave propagation and has little effect on perceived width. Overall, the data suggest that the suspended ceiling diffusers and the room's generous width work together to provide consistent, moderate spatial envelopment throughout the audience area.

## Conclusions

The measurement campaign in Vatroslav Lisinski Concert Hall shows that the hall delivers consistent acoustic conditions across three representative source locations. Reverberation times are optimal for symphonic music, yet still acceptable for reinforced speech. Clarity indices reveal moderate speech definition and adequate musical detail. IACC indicate good spatial openness.

### Comparison

Relative to recent medium-sized “vineyard” rooms (e.g., Helsinki Music Centre, Lucerne KKL), Lisinski exhibits slightly longer decay and lower clarity, however, the values align well with other 1970s shoebox designs of similar capacity. Compared with the author's measurements in nineteenth-century horseshoe theatres Lisinski offers tighter control of reverberation and far greater uniformity. The suspended reflector cloud and broad side walls replace the multi-storey balconies of traditional opera houses.

The data confirm that Lisinski can support a mixed programme of symphonic, amplified speech, and choral repertoire with minimal acoustic adjustment. Minor interventions could fine-tune clarity for spoken-word events without compromising musical warmth.

## Acknowledgment

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