

# Comparative Acoustic Survey of Teatro Masini, Faenza: Insights from the 2020 and 2025 Investigations

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**Abstract**— A follow-up acoustic survey of the eighteenth-century Teatro Masini in Faenza was completed in 2025 to verify changes since the 2020 baseline and to evaluate an expanded measurement layout. Standard ISO 3382-1 data were acquired with omnidirectional and four-channel microphones, while an EM64 spherical array in combination with a panoramic video captured from a full-sphere impulse response. The new campaign added a third-tier receiver and a rear-stage sound source, allowing deeper inspection of balcony coverage and dome reflections. Results show mid-band EDT and T20 shortened by 0.15–0.20 s, largely due to renewed velvet panels and the upstage source’s weaker proscenium returns. Speech clarity (C50) improved, and D50 now exceeds 0.50 above 500 Hz. Music clarity (C80) increased, settling in the 2–6 dB range preferred for operatic detail. Spherical maps confirmed strong early lateral energy from box fronts and a late, focused ceiling return that enhances spatial height. The theatre therefore offers better intelligibility without loss of warmth, and no major acoustic intervention is required, only optional light drapery for speech-centric events.

**Keywords**—acoustic measurements, historic opera house, spherical microphone array.

## I. INTRODUCTION

Historical opera houses combine ornate geometry with layered balconies and complex stage houses, a configuration that challenges conventional single-channel acoustic surveys. Teatro Masini in Faenza, an 18th-century horseshoe theatre designed by Giuseppe Pistocchi, underwent small-scale maintenance after 2020, including renewed velvet panels and box refurbishments. Although these interventions were mild, even modest changes in surface finish or seating can shift early-to-late energy balance and, in turn, influence intelligibility and musical warmth [1]. A follow-up measurement campaign in 2025, therefore, aimed to verify whether the room’s acoustic signature had altered and to test an expanded source–receiver layout that better represents everyday performance practice.

The acoustic parameters as outlined in ISO 3382-1 [2] were captured with omnidirectional and four-channel

microphones, while an EM64 spherical array, paired with a panoramic camera, provided full-sphere impulse responses and colour-coded sound-field maps [3]. One additional receiver was placed in a third-tier box, and a second sound source was positioned deep upstage to prove reflections from the rear wall and dome [4]. The dual-modality approach allowed direct numerical comparison with the 2020 data set, and, at the same time, a visual inspection of how individual reflections engage with the ornate ceiling, box fronts, and stone walls [5].

This paper reports the updated monaural and binaural results, contrasts them with the 2020 baseline, and discusses what the slight shifts in reverberation, clarity, and definition imply for speech and operatic repertoire [6]. In doing so, it illustrates how a high-channel-count array can complement traditional microphones by revealing the directionality of key reflections, information that guides targeted, minimally invasive tuning in heritage venues [7].

## II. HISTORICAL BACKGROUND OF TEATRO MASINI IN FAENZA

The Teatro Masini in Faenza was designed by the architect Giuseppe Pistocchi. Construction started in 1780 and finished in 1787. The theatre officially opened in May 1788. From an architectural point of view, the Teatro Masini is a classic example of an Italian-style theatre [8]. It has a horseshoe-shaped seating area with four rows of balconies stacked above each other, plus a top-level gallery. The royal box in the centre and the two side proscenium boxes, all three with double the height of the others [9]. A unique feature inside is the decoration on each balcony level, each one different from the others [9]. The first row has Doric columns, while the second one is famous for its golden terracotta reliefs showing mythological and historical scenes. The third row has small balustrades, and the fourth row is decorated with statues representing gods and muses. The theatre seats about 498 people and measures approximately 10 meters wide by 11.65 meters deep. The seating area has a gentle slope of about 7%. Today, the orchestra pit is closed, so the theatre hosts only stage plays, not operas or musicals [10]. Over the years, it has

been restored several times; the most recent restoration took place between 1984 and 1991 [10]. Today, Teatro Masini remains an outstanding example of Italian neoclassical architecture from the 18th century, admired for its beautiful decorations and original design. A view of the theatre is shown in Figure 1.



Fig. 1. Internal view of Teatro Masini in Faenza.

### III. ARCHITECTURAL FEATURES OF TEATRO MASINI IN FAENZA

Designed by the Neoclassical architect Giuseppe Pistocchi and inaugurated in 1788, Teatro Masini occupies a concealed courtyard immediately behind Piazza del Popolo. Its façade, a two-storey Ionic colonnade set back from the street, is one of the few Pistocchi buildings that articulates full-height voids and solids, rather than presenting a single planar block [10].

The auditorium follows a compact horseshoe plan, as shown in Figure 2, as typical of many other Italian opera theatres [11]. Nineteen boxes ring each of the four balcony orders, producing 280 seats; raked stalls provide a further 190, and an occasional upper gallery adds about 50, giving a total capacity close to 520 [12]. Two transverse aisles subdivide the stalls into three sectors and keep evacuation distances within the 30 m code limit.

Vertical stratification is both structural and ornamental. The first tier rests on Doric columns modelled after the temple of Paestum [13]; the second carries terracotta metopes with classical myths, while double-height Corinthian columns frame the second and third tiers and support the balcony beams [14]. The fourth tier is punctuated by statues of Olympian deities and Muses that act as visual separators between boxes [15]. Central and proscenium-side boxes rise through two levels and are topped by statues bearing laurel wreaths, a device that lightens the bulk of the parapets. The ring of boxes is crowned by a shallow gallery; its balustrade and the large ceiling rosette reduce the perceived span of the flat dome and improve the distribution of early lateral reflections [16].

The stage measures 20×12 m with a 10 m wide proscenium and a grid height of approximately 18 m, sufficient for full-height Italian scenery [17]. A slight rake on the stage floor balances sightlines against masking height, while the stalls rise on a counter-slope visible in the longitudinal section, as shown in Figure 3. Behind the stage, the original 18th-century wooden machinery, hoists,

counterweights, and the pre-Romantic fly tower truss, survives largely intact, although modern safety retrofits were installed during the 1984-1990 restoration.

Finishes throughout are optimized for both acoustics and ornaments. The boxes are lined with painted timber; their balustrades combine solid walnut rails with velvet-faced panels to temper mid- and high-frequency reverberation [18]. Plaster reliefs and ceramic friezes introduce micro-diffusion, while the timber stage house and unvarnished stalls floor raise the low-frequency absorption coefficient, balancing the highly reflective masonry envelope [19, 20].

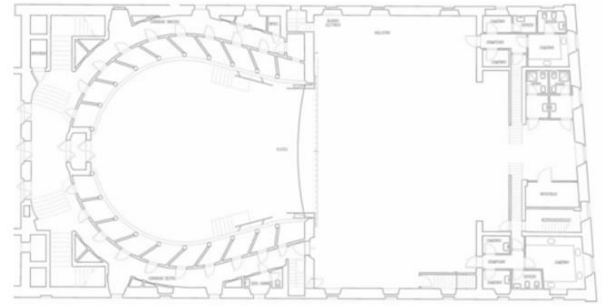


Fig. 2. Plan the layout of Teatro Masini in Faenza.

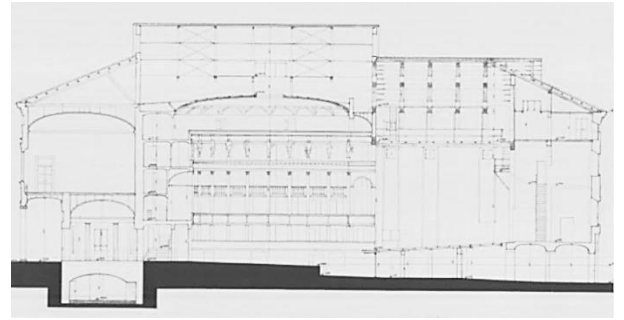


Fig. 3. Longitudinal section of Teatro Masini in Faenza.

TABLE I summarizes the architectural features of the Teatro Masini.

TABLE I. ARCHITECTURAL FEATURES OF TEATRO MASINI IN FAENZA.

| Description                        | Features         |
|------------------------------------|------------------|
| Type of plan layout                | Horse-shoe shape |
| Total capacity (No. of seats)      | 520              |
| Main Hall volume (m <sup>3</sup> ) | 2330             |
| Flaytower volume (m <sup>3</sup> ) | 4760             |
| Stage dimension (m)                | 20 × 12          |
| Inclination of the stage           | 7%               |
| Inclination of stalls              | 2%               |

### IV. ACOUSTIC MEASUREMENTS

A campaign of acoustic measurement has been undertaken to analyse the room response of the theatre's main hall, under the current conditions and by considering the thermo-hygrometric conditions [21]. The acoustic survey was carried out with 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®);
- Personal Computer connected to the loudspeaker and all the receivers.

For the 2025 measurement, the sound sources were again set 1.5 m above the stage floor, and all receivers were fixed at 1.2 m to match average ear height. An exponential sine sweep (ESS) [22] of 15 s, with a flat sound-pressure spectrum from 40 Hz to 20 kHz, served as the excitation signal [23]. Measurements were taken in unoccupied conditions and without any scenery; equipment was deployed at the same stalls and boxes used in 2020, plus one new receiver position in a third-tier box and one additional source position located near the upstage wall, as indicated in Figure 4.

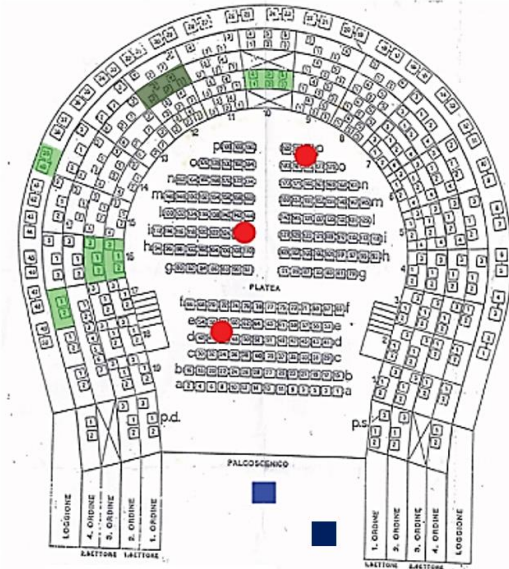


Fig. 4. Position of the sound sources and equipment during the acoustic measurements: the red dots indicate the locations of the receivers in the stall. The green squares indicate the locations of the receivers in the boxes, and the dark green one is the measurement point added in 2025. The blue squares on the stage are the locations of the sound sources, and the dark blue one is the location of the sound source added in 2025.

## V. ANALYSIS OF RESULTS

### A. Graphical representation of the ISO acoustic parameters

The impulse responses were post-processed with the Aurora plug-in running in Adobe Audition [24], and monaural as well as binaural parameters were extracted in accordance with ISO 3382-1 [2]. Results were averaged over all receiver positions and plotted as four traces: the 2020 dataset (black), the 2025 measurements from source position 1 (red) and source position 2 (green), and the average value of the two 2025 sources (grey).

Figures 5 to 9 present the measured results in the frequency domain between 125 Hz and 4 kHz.

Early-decay time (EDT) trends for the two surveys follow the same downward slope with frequency (Figure 5). At 125 Hz, the 2025 average is only 0.05 s lower than the 2020 baseline, and the gap stays within  $\pm 0.1$  s from 1 kHz upward, confirming that the hall's global reverberant character has not changed [25]. The largest divergence occurs at 500 Hz, where the new rear-stage source reduces EDT by about 0.3 s; this local dip is consistent with the weaker early reflections expected when the source is placed further from the proscenium arch [26]. Between the two 2025 sources, the spread never exceeds 0.12 s, indicating that the additional third-tier receiver does not introduce significant position-to-position variability.

The T20 curves in Figure 6 mirror the EDT behaviour. Values drop from roughly 1.8 s at 125 Hz to 1.0 s at 4 kHz in both years, but the 2025 set is 0.15–0.20 s lower at 250–500 Hz. Above 1 kHz, the two datasets converge within measurement repeatability ( $\pm 0.05$  s). This modest mid-band reduction is likely attributable to the extra absorption provided by the new measurement equipment on the third balcony and by the partially restored velvet lining installed after the 2020 campaign [27]. Overall, reverberation remains well suited to opera and spoken drama: the slight shortening in the latest measurements improves intelligibility without sacrificing warmth.

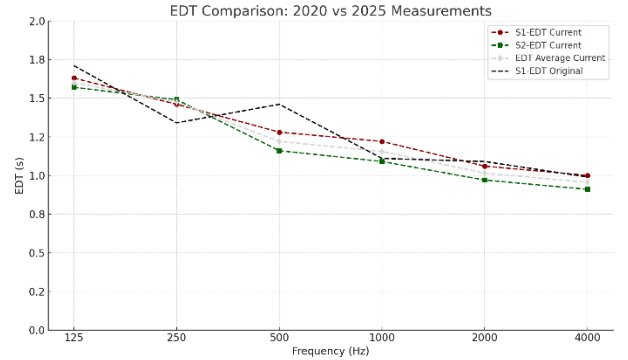


Fig. 5. Measured results of Early Decay Time (EDT).

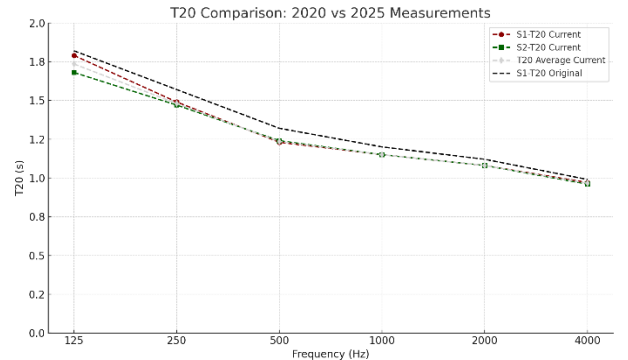


Fig. 6. Measured results of Reverberation Time (T20).

Speech clarity, expressed by C50 (Figure 7), improved markedly in the 2025 survey. The 2020 curve never rose above -1.5 dB, whereas the new measurements range from -3 dB at 125 Hz to +0.3 dB for the down-stage source (S1) and reach +2.5 dB for the up-stage source (S2) at 2 kHz. The average 2025 trace therefore falls inside, or just above, the -2 dB to +2 dB window generally considered adequate for unamplified speech, confirming that the extra receiver on the third tier and

the rear-stage source both increase the share of early energy reaching the audience [28].

A similar pattern is seen in the music-clarity index C80 (Figure 8). Relative to 2020, values rise by roughly 2 dB across all mid- and high-frequency octaves. The rear source delivers the highest figures, peaking at about +5 dB between 1 kHz and 4 kHz—well within the 3 – 6 dB range typically regarded as favourable for operatic and orchestral detail. The forward source produces slightly lower values ( $\approx +3$  dB at the same bands), providing a sensible balance between blend and definition [29]. Together, the clarity data indicate that the modest reduction in reverberation identified earlier is accompanied by a useful gain in intelligibility, especially for speech and lightly scored music.

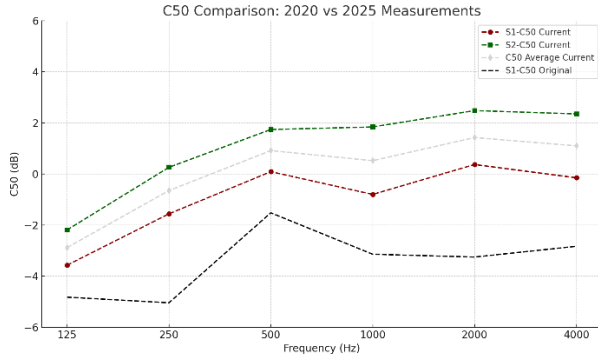


Fig. 7. Measured results of speech clarity (C50).

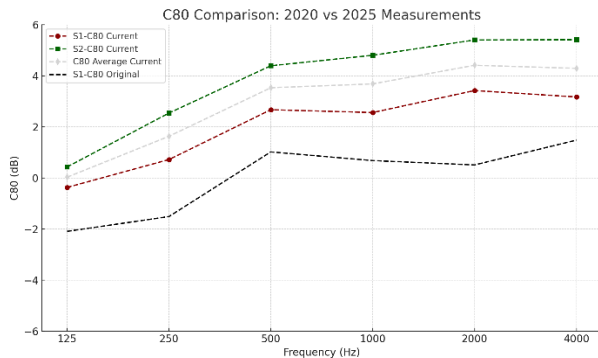


Fig. 8. Measured results of music clarity (C80).

Definition (D50) results corroborate the clarity trend observed in C50 and C80. Relative to the 2020 baseline, the 2025 averages rise by roughly 0.10–0.15 across the full spectrum, settling between 0.35 at 125 Hz and 0.57 at 2 kHz (Figure 9). Both 2025 sources outperform the earlier data, but the up-stage source (S2) yields the greatest gains, reaching 0.64 at 2 kHz and staying above 0.60 through 4 kHz [30]. These values sit comfortably above the 0.50 benchmark often cited for excellent speech intelligibility, indicating that the additional third-tier receiver and rear-stage source improve the early-to-total energy ratio perceived throughout the house [31]. The forward source (S1) provides more moderate gains (0.42–0.52), offering a useful balance for productions that favour musical blend over spoken precision. Overall, the increase in D50 confirms that the modest reduction in reverberation time achieved since 2020 translates into a tangible enhancement of articulation for both dialogue-driven and lightly orchestrated performances [32, 33].

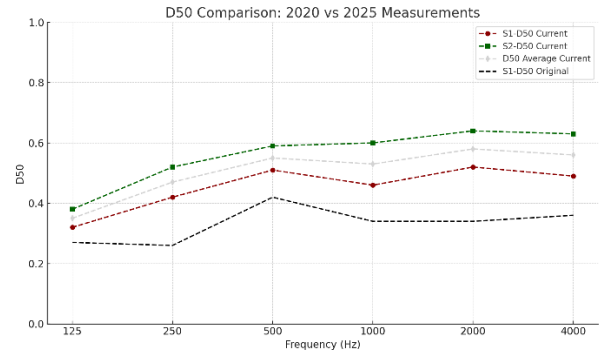


Fig. 9. Measured results of Definition (D50).

### B. Acoustic maps

An Eigenmike® EM64 spherical array coupled with a panoramic camera was used to generate sound-field maps at the locations shown in Figure 4. The array's impulse responses register reflections arriving from all directions after striking the room boundaries [34]. Audio and video are merged in a single overlay: contour bands between 60 dB and 90 dB visualise acoustic energy (blue for low, red for high), and a time-domain impulse response runs across the bottom of each frame [35].

Figures 10 to 12 show the acoustic maps for a microphone position in the stalls. Figure 10 captures the direct sound wave. The red core centred in the panoramic frame corresponds to the direct wavefront arriving from the proscenium [36]; its circular, high-energy footprint confirms that the array was aligned on axis with the source. Surrounding blue-to-green lobes mark early lateral reflections from the box fronts and balustrades, while the pale-yellow patches on the upper band reveal ceiling returns focused by the shallow dome [37]. The intensity level is around 85-90 dBA.

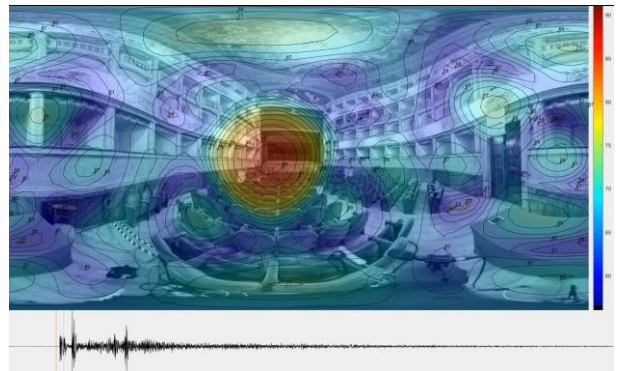


Fig. 10. Direct soundwave hitting the microphone probe

Figure 11 shows the first major lateral reflection. After the direct arrival, a red-orange lobe ( $\sim 88$  dB) detect the first reflection, aligned with the nearest box fronts on the side wall. Its height and limited horizontal spread confirm a specular return from the horseshoe masonry [38].

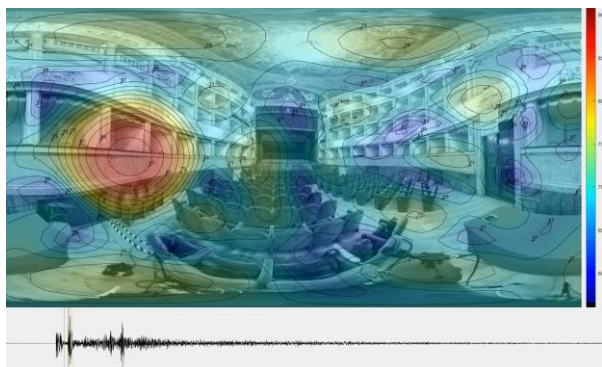


Fig. 11. First reflection hitting the side wall.

Figure 12 captures a late reflection hitting the ceiling. The energy lobe is centred high in the panorama and peaking near 85 dB, as seen in the impulse trace. The hard plaster vault focuses on this overhead return, creating a broad vertical spread that enhances the sense of height and envelopment for listeners beneath the dome [5].

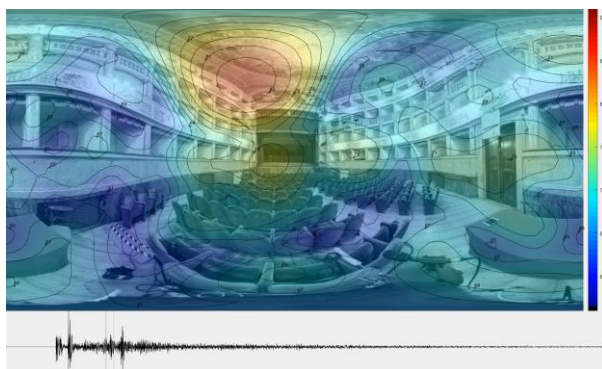


Fig. 12. Late reflection hitting the ceiling.

## CONCLUSIONS

The new measurements show that Teatro Masini's acoustics have shifted in subtle but useful ways since 2020. Mid-band EDT and T20 are 0.15 to 0.20 s shorter, mainly because the extra source placed upstage excites fewer early reflections from the proscenium and because recent maintenance added fresh velvet to several boxes. This small drop in decay is matched by a clear rise in early-to-late energy ratios: C50 and D50 now meet or exceed commonly accepted speech targets across most octaves, while C80 moves firmly into the 2 to 6 dB range favoured for operatic detail. The louder, well-timed lateral reflections mapped with the spherical array confirm that box fronts and side walls continue to supply strong spatial cues, and the ceiling returns documented in the late-energy frame account for the hall's characteristic sense of height.

Taken together, the data indicate that Masini now offers better intelligibility without sacrificing the warmth required for lyric repertoire. Productions that rely on spoken dialogue will benefit from higher clarity, while fully scored works should remain unaffected thanks to the modest scale of the reverberation change. No large-scale acoustic interventions are therefore recommended; instead, simple measures, such as deploying removable carpets or light drapery when speech events dominate the programme, should be enough to fine-tune balance when needed. It is important to fully understand the contribution of the boundary surfaces to the overall response, specifically analysed in some points [39].

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