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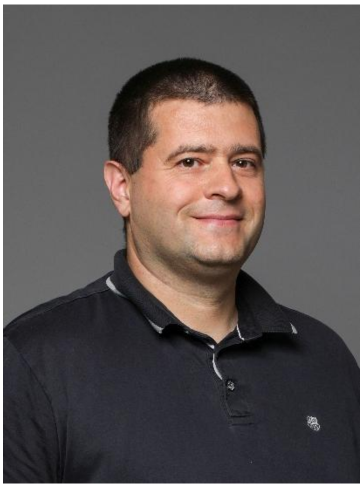

Welcome to the 11th Congress of the Alps Adria Acoustics Association (AAAA 2025)!

The congress will be held in Varaždin, Croatia, on 18 and 19 September 2025.

The Alps Adria Acoustics Association (AAAA) was founded by the acoustical societies of Austria, Croatia and Slovenia in 2002 as a new regional association. In 2019 the Hungarian Scientific Society for Optics, Acoustics, Motion Picture and Theatre Technology (OPAKFI) replaced the Austrian Acoustics Association as the new member of the AAAA. The original goal of the AAAA was to promote all aspects of research in the field of acoustics in the region. In addition, the aim was to improve the overall cooperation among the countries and their respective national societies.

Every two years, one of the three member societies of the AAAA organizes a scientific congress on acoustics. The main goal of these congresses is to bring together acousticians from Croatia, Hungary and Slovenia, as well as from the other European countries, to exchange knowledge, share research outcomes and strengthen cooperation among these societies for the benefit of the whole region. The last event took place in Izola, Slovenia in 2023.

The AAAA 2025 is organized by the Acoustical Society of Croatia (HAD), acting on behalf of the Alps Adria Acoustics Association.

During congress days, national and international experts will be given the opportunity to present scientific and applied papers on their research and professional activities in all fields of acoustics. Eminent international experts have been invited as keynote lecturers to present the latest developments in their respective fields.

The AAAA 2025 covers a broad range of topics that are the focus of interest in the scientific community and among researchers working in the industry. Congress topics include (but are not limited to) architectural and building acoustics, auditory and speech acoustic, environmental and transportation noise, machinery noise and vibration control, computational acoustics, electroacoustics, legislation in acoustics, musical acoustics, measurement techniques, nonlinear acoustics, psychoacoustics and perception of sound, soundscape, signal processing, sound generation and radiation, ultrasound, hydroacoustics, and many others.

Looking forward to meeting you in Varaždin in September 2025!

Marko Horvat,
Congress Chair

Programme overview

Thursday, 18 September 2025

	ROOM A	ROOM B	
08:00 – 09:00	Registration		*08:00 – 09:00*
09:00 – 09:30	Opening ceremony		*09:00 – 09:30*
09:30 – 10:20	Keynote lecture 1 - Louena Shtrepi		*09:30 – 10:20*
10:20 – 11:10	Keynote lecture 2 - Francesco Aletta		*10:20 – 11:10*
11:10 – 11:40	Coffee break		*11:10 – 11:40*
11:40 – 12:10	Presentation of exhibitors and sponsors		*11:40 – 12:10*
12:10 – 12:30	Soundscape	Industrial noise, vibrations, flow acoustics	*12:10 – 12:30*
12:30 – 12:50			*12:30 – 12:50*
12:50 – 13:10			*12:50 – 13:10*
13:10 – 14:30	Lunch		*13:10 – 14:30*
14:30 – 14:50	Building acoustics	Audio processing	*14:30 – 14:50*
14:50 – 15:10			*14:50 – 15:10*
15:10 – 15:30			*15:10 – 15:30*
15:30 – 15:50			*15:30 – 15:50*
15:50 – 16:10			*15:50 – 16:10*
16:10 – 16:40	Coffee break		*16:10 – 16:40*
16:40 – 17:00	Building acoustics (continued)	Audio processing (continued)	*16:40 – 17:00*
17:00 – 17:20	Environmental acoustics	Virtual acoustics and AI	*17:00 – 17:20*
17:20 – 17:40			*17:20 – 17:40*
17:40 – 18:00			*17:40 – 18:00*
18:00 – 18:20			*18:00 – 18:20*
20:00 – 23:00	Conference dinner		20:00 – 23:00

Friday, 19 September 2025

	ROOM A	ROOM B	
08:30 – 09:00	Registration		*08:30 – 09:00*
09:00 – 09:50	Keynote lecture 3 - Marjan Sikora		*09:00 – 09:50*
09:50 – 10:40	Keynote lecture 4 - Herbert Müllner		*09:50 – 10:40*
10:40 – 11:10	Coffee break		*10:40 – 11:10*
11:10 – 11:30	Psychoacoustics and audiology	Room acoustics	*11:10 – 11:30*
11:30 – 11:50			*11:30 – 11:50*
11:50 – 12:10			*11:50 – 12:10*
12:10 – 12:30		Education	*12:10 – 12:30*
12:30 – 12:50			*12:30 – 12:50*
12:50 – 13:10	Closing ceremony		*12:50 – 13:10*
13:10 – 14:30	Lunch and farewell coffee		*13:10 – 14:30*

Detailed programme

Thursday, 18 September 2025

08:00 – 09:00 Registration

09:00 – 09:30 **Opening ceremony**

09:30 – 10:20 **Keynote lecture 1**
Challenges in Architectural Acoustics for Sustainability
Assoc. Prof. Louena Shtrepi, Politecnico di Torino, Department of Energy "Galileo Ferraris"

10:20 – 11:10 **Keynote lecture 2**
Soundscapes and Public Health: from noise reduction to well-being promotion
Dr. Francesco Aletta, University College London, Institute for Environmental Design and Engineering

11:10 – 11:40 **Coffee break**

11:40 – 12:10 **Presentation of exhibitors and sponsors**

Soundscape **Room A**

12:10 – 12:30 *Melissa Ferretti, Davide Chiarella, Alessandra Cinini, Paola Cutugno*
Mapping perceptual lexicons: a semantic comparison between Italian and French descriptors of soundscapes

12:30 – 12:50 *Karlo Filipan, Mia Šetić Beg, Dominik-Borna Ćepulić, Hrvoje Štefančić*
Evaluation of soundscape perception in earthquake-affected urban spaces

12:50 – 13:10 *Mia Suhanek, Petra Predrijevac, Ivan Djurek, Antonio Petošić*
Evaluating the songbirds: acoustic analysis in a typical soundscape

* * *

Industrial noise, vibrations, flow acoustics **Room B**

12:10 – 12:30 *Andrej Biček, Janez Luznar, Igor Markic*
Optimizing vibroacoustic performance on EC motors for next-generation of battery-powered appliances

12:30 – 12:50 *Nejc Cerkovnik, Andrej Hvastja*
Separation of acoustic and hydrodynamic pressure components in jet flow using empirical mode decomposition

12:50 – 13:10 *Amar Trobradović, Antonio Petošić*
Analysis of acoustic emission signal in industrial power plants for classification of machine failure

13:10 – 14:30 **Lunch**

Building acoustics **Room A**

14:30 – 14:50 *Rok Prislan, Urban Kavka, Maximilian Neusser*
Experimental evaluation of the combined effect of gravel and a floating floor system on the impact sound insulation of a mass timber floor – is there an optimal composition?

14:50 – 15:10 *Maro Puljizevic, Milan Grasic, Tadej Poljansek*
Improving impact sound insulation of cross-laminated timber (CLT) floor-ceiling constructions – case study

15:10 – 15:30 *Mateja Nosil Mešić, Zoran Veršić*
Overview of regulations and national standards related to noise protection and acoustics in educational buildings

15:30 – 15:50 *Mateja Dovjak, Lucija Klinc, Ferdinand Deželak, Aljoša Flander, Klara Kopavnik, Peter Dolenc, Rok Zule*
Sound insulation in modern timber construction: a case study of a semi-detached building

15:50 – 16:10 *Jaroslav Hruškovič*
Case-study: comparison of building sound insulation (R'_w) and laboratory values (R_w) in lightweight constructions

* * *

Audio processing **Room B**

14:30 – 14:50 *Zvonko Lelas, Antonio Petošić*
Phase vocoder implementation

14:50 – 15:10 *Patrick Mraz, Antonio Petošić*
Development of a real-time acoustic signal analysis system on the Android mobile platform

15:10 – 15:30 *Josip Skledar, Kristian Jambrošić*
Tambura sound synthesis using the Karplus-Strong algorithm

15:30 – 15:50 *Antun Slaviček, Kristian Jambrošić*
Efficiency of a computer application for real-time automatic intonation correction

15:50 – 16:10 *Vedran Planinec, Stjepan Šebek, Marko Horvat, Kristian Jambrošić, Vito Vrbić*
Audio stem separation: overview and emerging applications in industry and entertainment

16:10 – 16:40 **Coffee break**

Building acoustics (continued) **Room A**

16:40 – 17:00 *Luka Čurović, Jurij Prezelj*
Characterization of rooms used in interlaboratory comparison of field measurement of sound insulation in building

* * *

Audio processing (continued) **Room B**

16:40 – 17:00 *Christopher Gjørup, Caroline Gaudeoso, Sami S. Brandt*
Extending perceived stereo baseline with vector-based amplitude panning and polarity inversion

Environmental acoustics **Room A**

17:00 – 17:20 *Ivan Bublić, Ivan Tudor, Darije Varžić, Domagoj Jelošek, Josip Šerfezi*
Case study of large open air concert noise in Zagreb

17:20 – 17:40 *Franka Meštrović, Krešimir Burnać, Ivo Haladin*
Low height noise barriers and rail dampers: sustainable solutions for urban tramway noise mitigation

17:40 – 18:00 *Jure Murovec, Jurij Prezelj*
Narrowband spectral immission directivity measurements

18:00 – 18:20 *Jurij Prezelj, Katarina Mramor, Božidar Šarler, Luka Čurović*
Infrasound as wind-generated pressure oscillations or pseudosound

* * *

Virtual acoustics and AI **Room B**

17:00 – 17:20 *Toma Sikora, Marjan Sikora*
Modeling traditional Croatian music forms with generative AI

17:20 – 17:40 *Jurica Đerek, Marjan Sikora, Davor Meter*
Evaluating sound source localization in audio augmented reality in a real-world environment

17:40 – 18:00 *Davor Meter, Marjan Sikora, Mladen Russo, Yanxiong Li*
Are virtual reality environments suitable and applicable for scientific testing

Friday, 19 September 2025

08:30 – 09:00 Registration

09:00 – 09:50 **Keynote lecture 3**
Soundscape and Audio Augmented Reality - From Research to Commercialization
Prof. Marjan Sikora, University of Split, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture

09:50 – 10:40 **Keynote lecture 4**
Taste and Sound – Dinner with acoustical accompaniment
Herbert Müllner, TGM Vienna

10:40 – 11:10 **Coffee break**

Psychoacoustics and audiology **Room A**

11:10 – 11:30 *Ema Bradić, Mia Suhanek, Ivan Djurek, Antonio Petošić*
A holistic acoustic tally framework utilizing mood-influencing mechanisms of popular music

11:30 – 11:50 *Dorotea Požega, Mia Suhanek, Antonio Petošić, Ivan Đurek*
The sound of emotion: audio features that could help distinguish sad and happy music

11:50 – 12:30 *Roland Sottek*
Psychoacoustics – The Future is Now!

12:30 – 12:50 *Andrea Andrijašević, Sanja Grakalić-Plenković, Mirta Čulina*
Literary texts in auditory rehabilitation: a case study of Ivana Brlić-Mažuranić's Tales of Long Ago

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Room acoustics **Room B**

11:10 – 11:30 *Nika Šubic, Klemen Šubic, Martin Klun*
Challenges in temporary theatre design: a case study in acoustic optimization for a non-purpose-built space

11:30 – 11:50 *Muammer Yaman*
Acoustic design in ancient public buildings: a Hellenistic bouleuterion

11:50 – 12:10 *Teo Poldrugovac, Marko Horvat, Danijela Roksandić Vukadin*
Acoustic characteristics of Franciscan church architecture: a field study of the church of St. Francis in Pula

Education **Room B**

12:10 – 12:30 *Kristian Jambrošić, Marko Horvat, Vedran Planinec, Ivan Ucović*
Innovative pedagogical approaches to teaching acoustics in higher education

12:30 – 12:50 *Antonio Petošić, Mia Suhanek, Ivan Đurek, Darko Domičić*
Bad acoustic praxis in environmental noise measurement, modelling and protection

12:50 – 13:10 **Closing ceremony**

Presentation of two Best Young Researcher Contribution Awards

13:10 – 14:30 **Lunch and farewell coffee**

ACOUSTIC DESIGN IN ANCIENT PUBLIC BUILDINGS: A HELLENISTIC BOULEUTERION

Muammer Yaman[1]

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Abstract: In the Hellenistic period, the bouleuterion (council house) was a public space in which decision-making processes were carried out and speech acts were used for social communication. This study examined the acoustic properties of the New Bouleuterion at Aigai in the Hellenistic period using objective acoustic parameters. The building's original architectural form, material properties, and spatial proportions provide important clues as to how it served public speech practices during this period. The acoustic model of the bouleuterion was created and analyzed using acoustic simulation software to evaluate parameters such as reverberation time, early decay time, speech transmission index and sound pressure level distribution. Furthermore, the sound absorption properties were modelled using hypothetical period-specific materials, and evaluations were made using different combinations of sources and receivers. The simulation outputs of the New Bouleuterion at Aigai were used to discuss the effects of the room acoustics performance of the bouleuterion on receiver positions. This study aims to contribute to acoustic research on ancient public buildings, as well as reinterpreting the functional construction of historical buildings using modern technology. For future research, an interdisciplinary approach is recommended, integrating more detailed documentation of material data from the period, comparative acoustic analysis of different building types, and digital heritage applications.

Keywords: Acoustic design, ancient public buildings, archaeacoustics, bouleuterion, reverberation time,

1. INTRODUCTION

Research on determining the acoustic characteristics of historical buildings has been brought to the forefront during the restoration of historical buildings spanning different periods. Preserving the original sound qualities of such buildings and transferring them to the future was considered important for the continuity of both architectural restoration and performing arts [1, 2]. Over time, these efforts have expanded to preserve not only physical but also sensory and experiential qualities, paving the way for the formation of the concept of acoustic heritage. Acoustic heritage suggests that not only the visual but also the auditory identity of buildings should be preserved, and the preservation of this heritage plays a crucial role in terms of cultural continuity/sustainability, especially in places where oral communication, music, or religious rituals are significant [3-5]. In this context, the study of the spatial characteristics of historical buildings in an aural context has contributed to the development of an interdisciplinary field called archaeoacoustics in recent years. Archaeoacoustics brings together architecture, archaeology, physics, and digital technologies to understand the relationship of past societies with sound, the auditory experiences of spaces, and the cultural meanings of these experiences [6, 7]. Although studies in this framework focus on structures such as caves, monuments, temples, etc., recently speech-based public structures (such as bouleuterion, open-air theatre, basilica, odeon) have also been included in the scope of archaeoacoustics [8-10].

The Hellenistic period represents a period in which public decision-making processes met with architecture. In these periods, bouleuterion (council houses) are the buildings where the executive committee called boule, which implements the decisions of the popular assemblies in Hellenistic polis (Greek city-states) and performs certain administrative tasks, convenes [11]. It is thought that not only visual hierarchies but also auditory conditions to support speech/speech performance were taken into consideration in the planning of these buildings. However, since these buildings are nowadays mostly physically damaged or destroyed, it is not possible to directly measure their acoustic performance. For this reason, digital reconstructions and auralizations using acoustic simulation software offer the opportunity to evaluate the past sound performance of the space [12, 13].

This study aims to both contribute to the acoustic reevaluation of ancient public buildings and to offer an interdisciplinary approach to experiencing cultural heritage through digital technologies. For this purpose, the New

Bouleuterion in the ancient city of Aigai in Western Anatolia is analyzed, and an acoustic assessment of how this building hosted discourse practices in the Hellenistic period is presented. The acoustic model is based on the possible original architectural form, material properties, and spatial proportions of the building, and analyzed through objective parameters such as reverberation time (T_{30}), early decay time (EDT), speech transmission index (STI), and sound pressure level (SPL) distribution. In addition, scenario analyses were performed over different receiver positions assuming periodic material properties. In this way, changes in the auditory performance of the building according to different receiver positions were revealed, and inferences were made on the auditory qualities of the public communication environment in the past.

2. MATERIAL AND METHODS

In this study, the acoustic analysis of ancient public buildings according to their period characteristics was examined. For this purpose, the New Bouleuterion in the ancient city of Aigai, located within the borders of Manisa, Yunusemre in Western Anatolia, was used as a case study. First of all, a comprehensive literature review and on-site observations were made for the bouleuterion, and evaluations were presented accordingly. Then, a simulation-based methodology combining architectural reconstruction, material approach, and room acoustic analysis is adopted to investigate the acoustic performance of the New Bouleuterion at Aigai.

2.1. Case Study

Aigai is located near the village of Yunddağı Köseler, Manisa province. The archaeological remains are located at a fairly high altitude, just at the top of Mount Gün, known as the ancient Aspordenon, which is part of the Yund Mountains. It is 13 km from the Aegean Sea and 30 km from Bergama [14]. The Bouleuterion at Aigai is one of the important representations of the public architectural structures in the city as a clear indicator of the political structure of Aigai. Although there are some findings about the city, architecture, and settlement, the bouleuterion was unearthed during the archaeological excavations carried out between 2004-11. The investigations show that the bouleuterion is layered, and there are traces of another building underneath. The fact that the buildings built at two different times preferred the same location and the similarities in their architecture indicate that the function of both buildings was the same [15]. The excavation team named the lower layer the Old Bouleuterion (late 4th century BC) and the upper layer, which was built closer to the present day, as the New Bouleuterion (mid-2nd century BC). Although some architectural elements of the New Bouleuterion have been lost over time, it has survived to the present day in good condition since no building was built on top of it [11, 15-17] (Figure 1). Therefore, this study focuses on the New Bouleuterion at Aigai.

Figure 1. New Bouleuterion at Aigai after excavation (Aigai Excavation Archive)

The new bouleuterion is right next to the Upper Agora, which is understood to have been the social center of Aigai. A slope rising to the north of the Agora building on the plain was used for the bouleuterion. Agora Street, which provides transportation between the city gate and the Agora, passes in front of the bouleuterion. The new bouleuterion sits on a rectangular area measuring approximately 23*14.5 m and consists of three main sections. These main sections are Prytaneion (?), Cavea, and Portico from east to west (Figure 2). These sections are leveled about the slope. The Prytaneion is at the level of Agora Street and is independent of the hall. The Cavea (11.5*13.2 m) was raised by a terrace wall, and its floor was formed on the same level as the floor of the Upper Agora. It has 12 seating rows with a capacity of approximately 200 people. As the largest part of the building, the Cavea serves the stage (Orchestra) with its curvilinear stone seating rows (Theatron). The Theatron has two kerkides. There are two klimakes in the center and the north; although no traces of them have been identified, it is thought that there may have been klimakes in the south. The central klimakes is 50 cm wide with 24 steps and an average height of 15 cm. The seating rows were formed by laying slabs of stone in the form of crates and filling them with stones and soil. The semicircular orchestra (6.4 m in diameter) is supported on the ceiling of the Prytaneion by a wooden floor. In this area, the statue of Hestia Bollaia was erected on a pillar situated on the bedrock in the central part of the orchestra. The pillar was elevated to the floor level of the orchestra with a pedestal made of big, rectangular stone blocks. The entrance to the Bouleuterion is on the south and north (later closed) sides of the building. The portico (3*3.15 m) is a columned gallery along the western edge at the top. This section has a separate entrance door accessed by a staircase from the south. The portico opens directly to the Cavea with a colonnade consisting of four columns and two buttresses in Ionic style. For this reason, the portico is one of the areas where the entrance to the building is provided. In addition, six different statues were made in a niche (7.6*1.2 m) on the north wall, which was added later to the New Bouleuterion, to honor the benefactors (euregetes). [11,15-17].

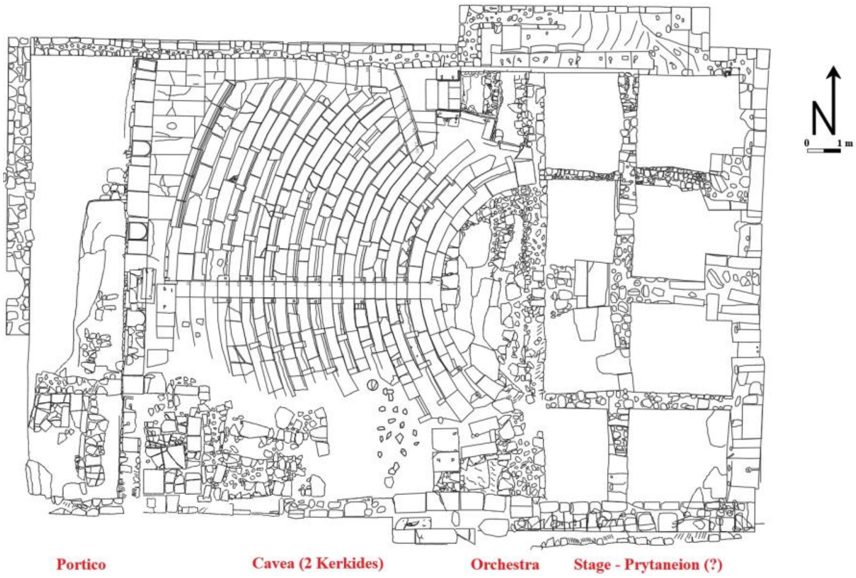

Figure 2. Plan of New Bouleuterion at Aigai (Aigai Excavation Archive)

The walls of the New Bouleuterion, the seating rows of the theatron, the columns in the Portico, and the pedestals are made of andesite stones, which are very suitable for processing (Figure 3). The lower parts of the walls of the building show that they were built with pseudo-isodomic masonry, and the upper parts with isodomic masonry. No mortar or clamp-like binding elements were used in the wall technique of the building. Clamps are seen only on some load-bearing blocks, and mortar is seen as white stucco only on the interior surface of the walls. The main reason for this practice, beyond decorative concerns, is considered to be the effort to provide a suitable acoustics in the space [18]. The roof of the Bouleuterion is covered with terracotta tiles. Wooden truss, exterior walls, portico columns, and two stone columns in the Cavea were used for supporting the long-span structure and the roof. All of the elements that make up the roof cage, such as purlins, rafters, and braces, as well as the floor of the second floor of the front rooms corresponding to the back of the orchestra, doors, and windows, were made of wood [16].

Figure 3. Panoramic view of the New Bouleuterion at Aigai (Photo taken by the author in July 2024)

2.2. Acoustic Simulation

The research adopted a simulation-based methodology combining architectural reconstruction, material approach, and room acoustic analysis to investigate the acoustic performance of the New Bouleuterion at Aigai [12, 13, 19-21]. The geometric model of the building was created by 3D modeling based on archaeological research and academic reconstructions [15]. Architectural parameters such as seating arrangement, ceiling height, and building geometry were modeled to reflect the assumed original configuration of the building in the Hellenistic period. The SketchUp program was used for 3D modeling (Figure 4).

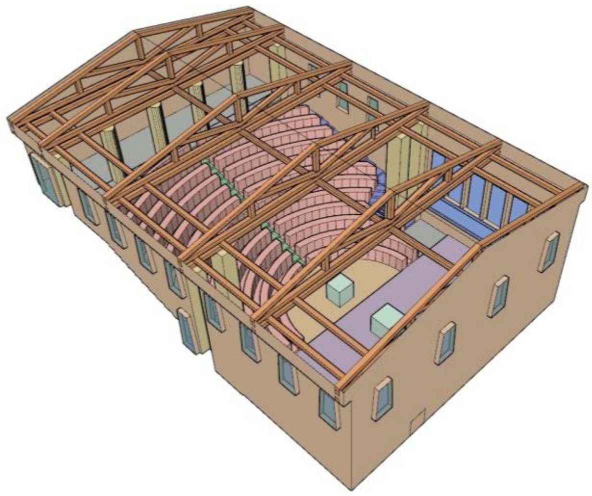

Figure 4. Acoustics model of the New Bouleuterion at Aigai

Acoustic simulations were performed using ODEON software (v14), a widely preferred tool for room acoustic analysis in cultural heritage studies. Objective parameters such as reverberation time (T_{30}), early decay time (EDT), speech transmission index (STI), and sound pressure level (SPL) distribution were calculated for different receiver locations, simulating typical speaker-listener arrangements in the bouleuterion. The simulation model includes hypothetical absorption coefficients derived from studies on historical building materials such as stone-marble and wood, and is programmed to reflect Hellenistic usage [5]. The sound absorption coefficients of the materials in the room are defined hypothetically and detailed in the simulation program (Table 1).

Table 1. Sound absorption coefficients of different materials used in the New Bouleuterion at Aigai

Materials *New Bouleuterion at Aigai*	**63 Hz**	**125 Hz**	**250 Hz**	**500 Hz**	**1000 Hz**	**2000 Hz**	**4000 Hz**	**8000 Hz**	α_w
Kerkides (Cavea)	0.16	0.16	0.24	0.56	0.69	0.81	0.78	0.78	0.5
Floor-Stairway-Klimakes	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.0
Walls	0.11	0.11	0.13	0.05	0.03	0.02	0.03	0.02	0.05
Column	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.0
Door & Window	0.19	0.19	0.14	0.09	0.06	0.06	0.05	0.05	0.1
Orchestra	0.19	0.19	0.14	0.09	0.06	0.06	0.05	0.05	0.1
Stage (on the Prytaneion)	0.19	0.19	0.14	0.09	0.06	0.06	0.05	0.05	0.1
Niche-Bema	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.0
Wood Truss-Ceiling	0.19	0.19	0.14	0.09	0.06	0.06	0.05	0.05	0.1

In acoustic simulations, a sound source (S1) was defined on the stage, and 12 receivers (R1-R12) were positioned at different points. 9 of the receiver points were defined at different points in the seating rows (in kerkides) and 3 in the Portico (Figure 5). In the room settings, the background noise was set to NC25. The total volume of the Bouleterion was determined as 2490 m^3. The active surface area for the sound field was calculated as 1500 m^2.

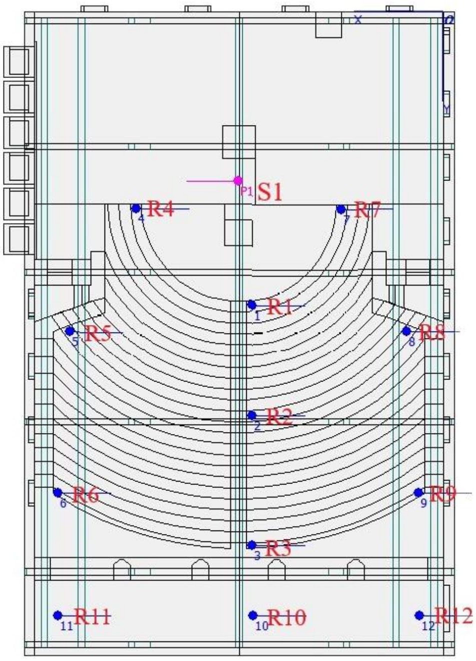

Figure 5. Source and receiver positions in acoustic simulations

Various scenarios were tested to assess the effects of varying receiver positions and material configurations on acoustic clarity and spatial sound distribution. The model was calibrated by comparing the results with data from similarly reconstructed Hellenistic spaces documented in the literature review. This methodological framework enables a systematic examination of how spatial and material factors shape the acoustic environment of the New Bouleuterion and its suitability for public oratory.

3. RESULTS AND DISCUSSION

In the research, acoustic investigations of the New Bouleuterion at Aigai were carried out according to the period conditions. A simulation-based analysis process was carried out in the investigations (Figure 6). The acoustic simulations of the New Bouleuterion provide important clues about the sound performance of the building. Considering the architectural form, material properties, and interior geometry of the building, the results are generally consistent with the historical context. However, some parameters point to the potential for improvement in terms of speech intelligibility.

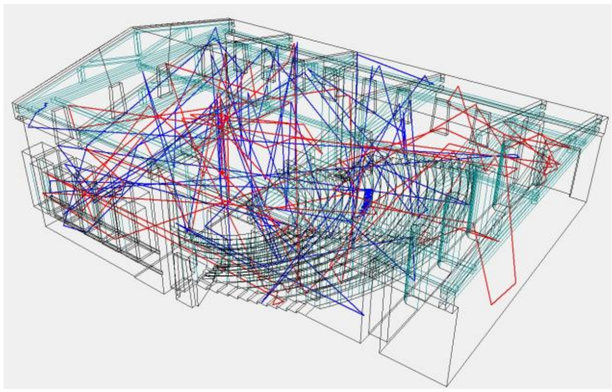

Figure 6. Ray tracing in acoustic simulations

Acoustic simulations performed on the New Bouleuterion structure show that the T_{30} (reverberation time) values, especially in the 500 Hz and 1000 Hz octave bands, are around 1.60 s and 1.70 s, respectively (Figure 7). These times are above the recommended optimum range of 0.8 - 1.2 s [22] for speech-based usage scenarios. The main reason for the high T_{30} values is the high reflectivity of natural stone surfaces in the floor, wall, and seating areas, and the fact that all surfaces are predominantly made of low absorption materials. Although these times are above the ideal level considering a speech-oriented function, considering the natural stone material, geometry, and large volume (2490 m^3), they are considered to be acceptable values within the historical context. The early decay time

(EDT) has a direct impact on speech intelligibility. In the simulations, EDT values were calculated in the range of 1.55 - 1.65 s in the 500 and 1000 Hz bands. These values are high in parallel with T_{30}, but the EDT is observed to decrease to 1.3 - 1.4 s, especially at the front row receivers (R4, R7). This suggests that early reflections are stronger in these regions and hence speech is better perceived. On the other hand, in the back rows (R11, R12), these times are as high as 1.7 s, indicating less reflection energy dissipation.

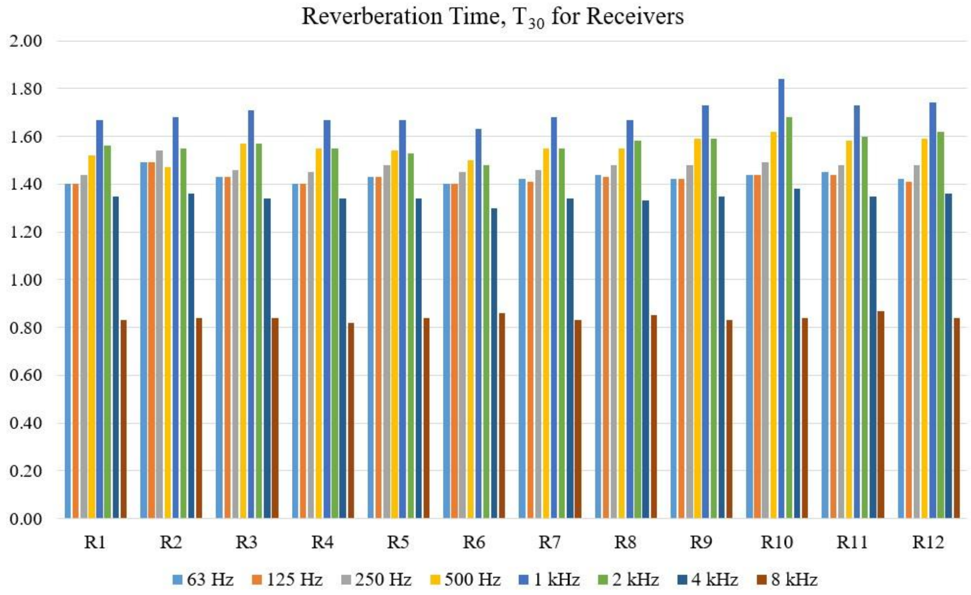

Figure 7. Reverberation time, T_{30} depending on the frequency spectrum at the receivers

Speech Transmission Index (STI) is critical for assessing the quality of speech transmission within the structure. The analysis revealed that STI values ranged from 0.38 to 0.52 at 12 receiver points. Especially at the front row receiver points (R4, R7), STI values exceed 0.50, which is between "fair" and "good" intelligibility. In contrast, at the receiver points located at the rear of the building (R10 - R12), the values fall below 0.40-0.45 and are considered "poor" [23] (Figure 8). This difference is due to the distance between the sound source and the receiver points, as well as the direction and intensity of the early reflections. The semi-elliptical seating arrangement and highly reflective stone surfaces of the New Bouleuterion provide limited lateral reflections. Therefore, the energy from the side walls is limited, and the attenuation of direct sound, especially in the rear areas, leads to a significant decrease in the STI.

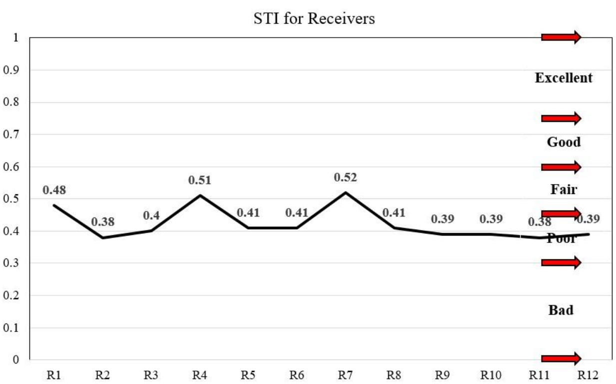

Figure 8. STI assessment for receivers

The SPL (A-weighted) values obtained by modeling the identified single-point sound source as 71 dBA, vary between 48.3-53.4 dBA for the 12 receiver points. In the front areas of the Cavea (e.g., R1, R4, R7), the SPL values remain at 51-52 dBA, while these values decrease as we move towards the rear areas. In particular, 48.3 dBA was measured at R12 (Figure 9). There is a total sound pressure level difference of 5 dB across the New Bouleuterion. This is explained by both the increase in the source-receiver distance and the concentration of sound primarily in the frontal zone. However, the geometry and surface characteristics of the building lead to focused reflections in certain areas, resulting in localized SPL increases.

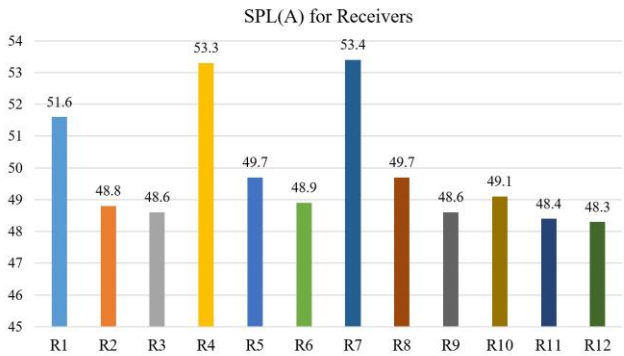

Figure 9. Source-dependent A-weighted sound pressure levels SPL(A) for receivers

The results of the analysis reveal that the New Bouleuterion at Aigai provides an effective speech environment in the context of Hellenistic public buildings, but needs some improvement in terms of contemporary acoustic standards. Studies on similar buildings have also reported that the lack of lateral reflections and high reverberation times limit speech intelligibility [12, 24]. The use of materials with low absorption coefficients, the lack of diffuse reflectivity of the stone, and the absence of directed reflectors limit the sound quality, especially rear the bouleuterion (Portico). This is confirmed by the reduced STI and SPL values at certain receiver points in the simulations. The strategic use of acoustic panels, local reflective elements, and diffusers in future re-functioning or conservation-based interventions on this building has the potential to improve performance without compromising the original material characteristics.

4. CONCLUSION

This study investigated the acoustic performance of the New Bouleuterion in the ancient city of Aigai through simulation analysis based on architectural reconstruction and material assumptions. The findings revealed that although the building was constructed without the acoustic design tools of the period, it has appropriate spatial and material arrangements that allow public speeches to take place. The reverberation time (T_{30}) values obtained in the 500 - 1000 Hz frequency range are between 1.6-1.7 s, indicating the presence of a reflective environment, a typical result of stone-based architecture. However, these values may have limited speech intelligibility in some seating areas. Early decay time (EDT) and speech transmission index (STI) analyses show a gradual decrease in intelligibility from the front rows to the back rows, while relatively higher acoustic clarity is observed at the front receiver locations such as R4 and R7. The sound pressure level (SPL) distribution also reveals a significant decrease in the rear sections, which is attributed to both the directional character of the sound source and the limited lateral reflections due to the geometry of the building.

Although the building does not meet today's speech clarity standards, it can be argued that it provides a historically consistent and functional acoustic environment, considering the period and context in which it was located. This study demonstrates that the integration of digital modeling and archaeological data can provide important insights into ancient audience experiences. Future studies are recommended to conduct comparative analyses with different bouleuterion examples, calibrate material data with in-situ measurements, and use virtual auditory-auralization reconstructions for education and cultural heritage awareness. Especially in the protection of intangible cultural heritage, preserving and making understandable auditory values is considered important.

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