REMEDIAL ACOUSTICS IN MONUMENTAL LECTURE AUDITORIA OF NEOCLASSICISM IN ATHENS

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1 INTRODUCTION

Neoclassicism was established and dominated in Greece in the second half of the 19th century. At that time, several neoclassical public buildings were built, including lecture halls, such as the ex-Royal Palace (now the building of the Greek Parliament), the Averof building of the National Technical University of Athens, the University of Athens, etc. The lecture halls of this category are distinguished for the quality of their proportions, the correct scale, the gentle style and the sculptural and not only décor. However, there is a common flaw, which is the problematic acoustics of the rooms. This is related to the architectural choices of the rooms that systematically ignore the rules of acoustic design, since, admittedly, architectural acoustics became a science much later, i.e just at the turn of the 19th century. What exacerbates the problem is that the possibility for remedial acoustic design of the rooms is extremely limited due to the necessity of preserving / respecting their historical character.

This study uses four examples of neoclassical auidtoria, namely the Kaftantzoglou Hall of the Averof Building of the National Technical University of Athens[1], theCeremonial Hall and the Eastern Hall of the Academy of Athens, as well as the Hall of the Greek Parliament. Based on acoustic measurements in situ, problems, and solutions that were adopted in order to correct their acoustics, are presented and commented on.

2 PROBLEMS IN THE ACOUSTICS OF NEOCLASSICAL LECTURE HALLS

The characteristic problem of these halls is the disproportionate volume in relation to their surface area and capacity, which is connected with their monumental height (Table 2.1, Fig. 2.1-2.4). This has as a consequence, on the one hand, the relatively high reverberation (Fig. 3.1) and, on the other hand, extremely delayed intense reflections (echoes) from the ceiling (Fig. 2.1-2.4) which drastically reduce the intelligibility of speech in the space[2]. Echoes can also arrive from remote walls of the space, as happens in the Kaftantzoglou Hall with the wings on either side of the speaker (Fig. 2.1), in the Ceremonial Hall of the Academy of Athens with the back wall (Fig. 2.2), etc. Moreover, when the shape of the reflective surfaces is curved, sound focusing is added to the echo problem (sections Fig. 2.1).

The above-mentioned design faults of Neoclassical lecture halls are evident due to their highly reflective internal shell. This usually consists of stone, either plastered (Fig. 2.1) or marble-clad (Fig. 2.2, 2.4), or even skylights in the ceiling with the aim of enhancing natural lighting in the space (Fig. 2.4). However, despite their reflective shell, these rooms generally do not have surfaces near the audience (reflectors) that send direct early reflections (Fig. 2.1, 2.4). The latter is also confirmed by the on-site measurements of Definition (or D_{50}), i.e. the ratio of the early received sound energy (0-50 ms after direct sound arrival) to the total received energy (Fig. 3.2). But neither is there any concern for the direct sound to reach the audience intact, for example seats outside the solid angle of 140° from the speaker, suffer because of the limited directionality of the sound there (Fig. 2.1, 2.4). Also, in this category of rooms (which are usually designed to also serve as ceremonial halls), there is generally no slope in the audience floor for obvious reasons, resulting in both visual and acoustic rays from the speaker being hindered.

Table 2.1 Basic details of the test halls

Lecture hall	**Kaftantzoglou Hall, National Technical University of Athens**	**Ceremonial Hall, Academy of Athens**	**Eastern Hall, Academy of Athens**	**Hall of the Greek Parliament**
Construction date	1878	1887	1887	1836
Architect	Lysandros Kaftantzoglou	Ch . Hansen, E. Ziller	Ch . Hansen, E. Ziller	Friedrich von Gaertner
Volume (m^3)	5800	2530	2600	6000
Capacity (people)	175	240	190	520
Volume per person (m^3/person)	33,0	10,5	13,7	11,5
Area (m^2)	446,0	247,0	345,0	460,0
Width (m)	40,0	12,5	11,1	20,0
Length (m)	18,0	19,9	28,5	20,0
Height (m)	10,0 - 17,0	9,4 - 11,4	6,0 - 6,9	15,0
RT_{mid}* (s)	3,45	2,2	2,3	1,7
* : mid-frequencies (average of 500, 1000 Hz), unoccupied				

The thick load-bearing masonry of neoclassical rooms is inherently soundproof, with the exception of the glazing they may have. These are designed with single panes of glass and cannot withstand modern urban noise pollution, which is confirmed by the present on-site measurements. (Fig. 3.3). Of course, the characteristics of these rooms are the decoration they have, which contributes to rich diffuse sound. For example, the vaulted ceilings that bridge the large openings in the lecture halls of the time, prevent the creation of echoes and contribute to the acoustic uniformity of the space (Fig. 2.2, 2.3).

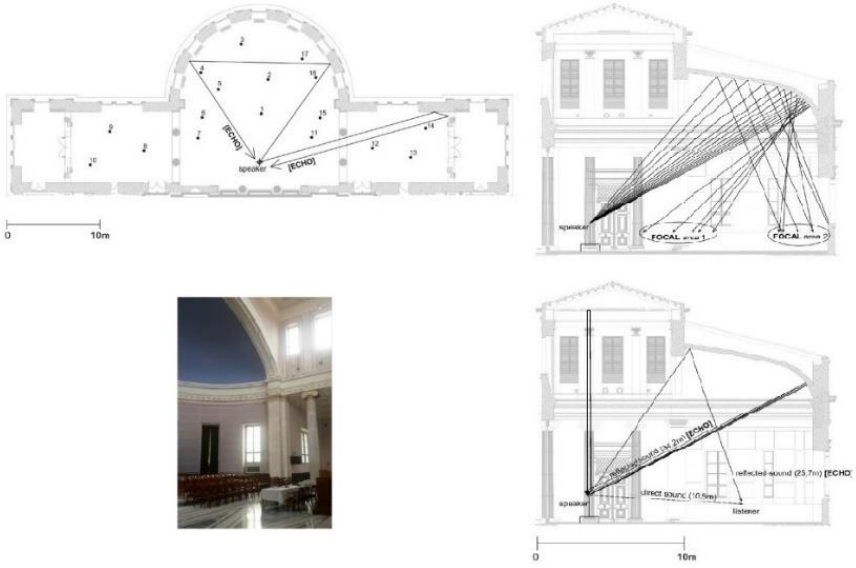

Figure 2.1 Plan, sections, and side view of the Kaftantzoglou hall of the Nat. Tech. Univ. Athens

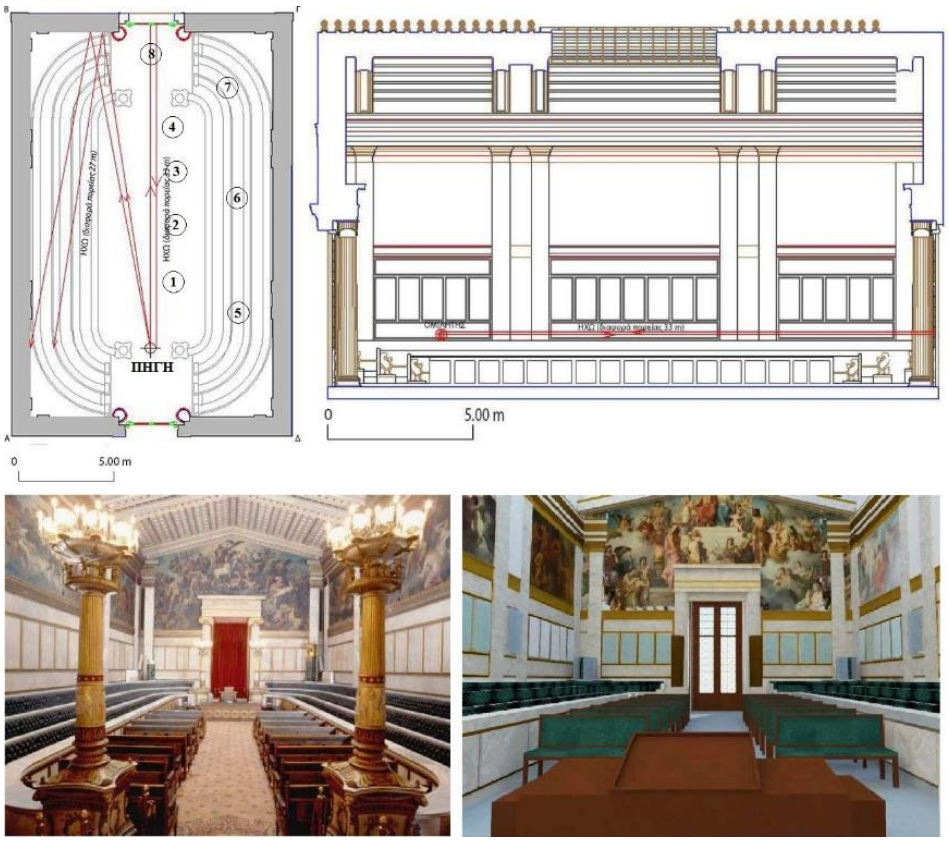

Figure 2.2 Plan, section, and front view before intervention (left) and rear view after intervention (right) of the Ceremonial Hall of the Academy of Athens

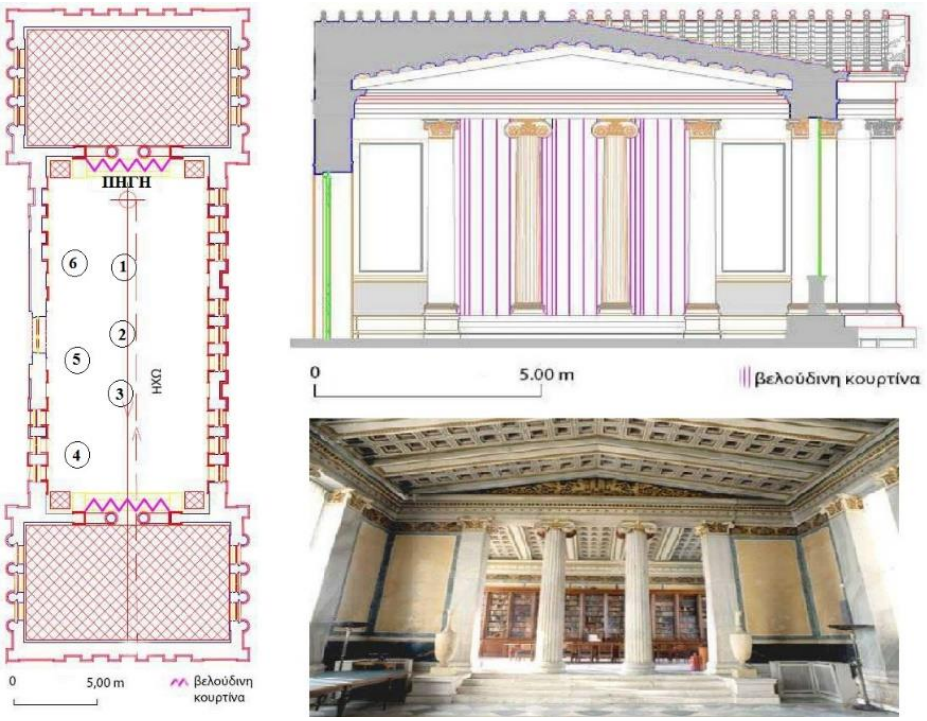

Figure 2.3 Plan, section, and front view of the Eastern Hall of the Academy of Athens.

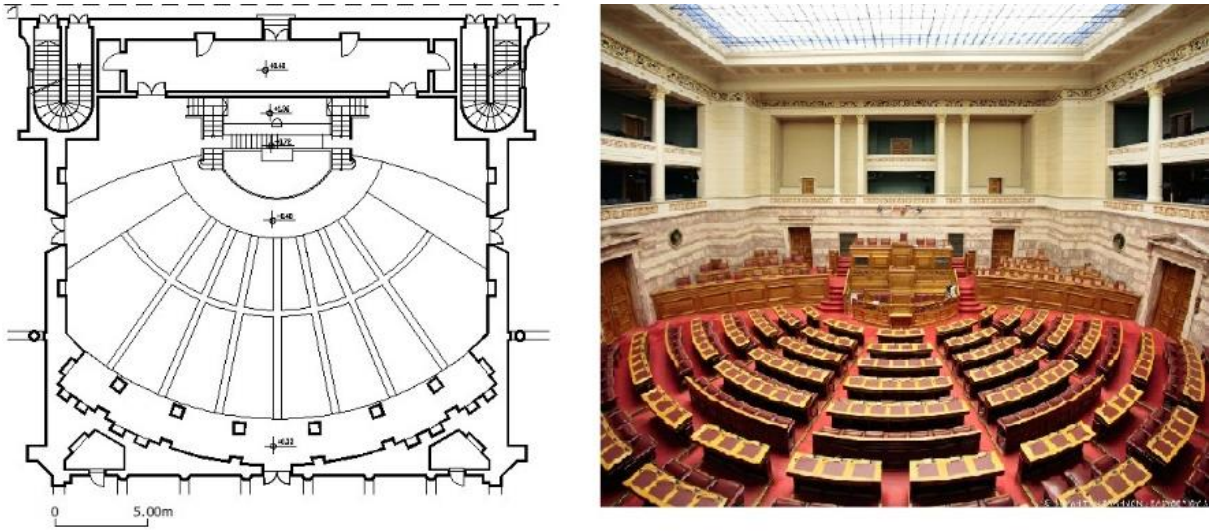

Figure 2.4 Plan and front view of the hall of the Hellenic Parliament

3 ACOUSTIC MEASUREMENTS

Acoustic measurements were performed without an audience according to relevant ISO standards and with state-of-the-art Brüel & Kjær equipment. Monophonic recordings of the room response to a simple waveform (impulse response) were used with the help of an isotropic sound source at the speaker's position. Different measurement positions were used in each room (Fig. 2.1–2.4).

The parameters used are shown in Table 3.1; measurements were performed in the octave bands from 125 Hz to 4000 Hz with the help of the Dirac software. In this paper, results are presented at mid frequencies (500 Hz, 1000 Hz), with the exception of the reverberation time and ambient noise measurements that are given throughout the spectrum (Fig. 3.1–3.3).

Table 3.1 Physical parameters measured

Physical parameter	**Symbol**	**Units of measurement**
Reverberation time	RT	seconds
Early Energy Fraction	D_{50}	-
Ambient noise	L_{Aeq}	dBA

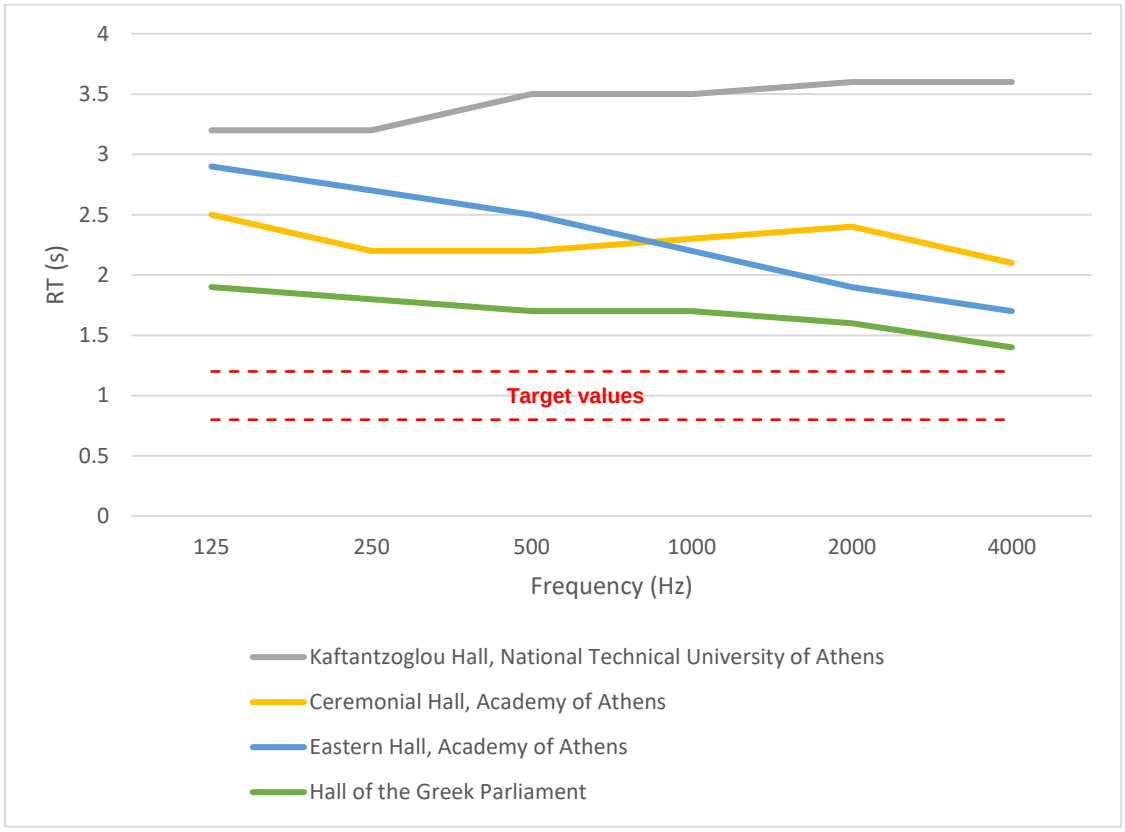

Figure 3.1 Measured Reverberation Time, unoccupi

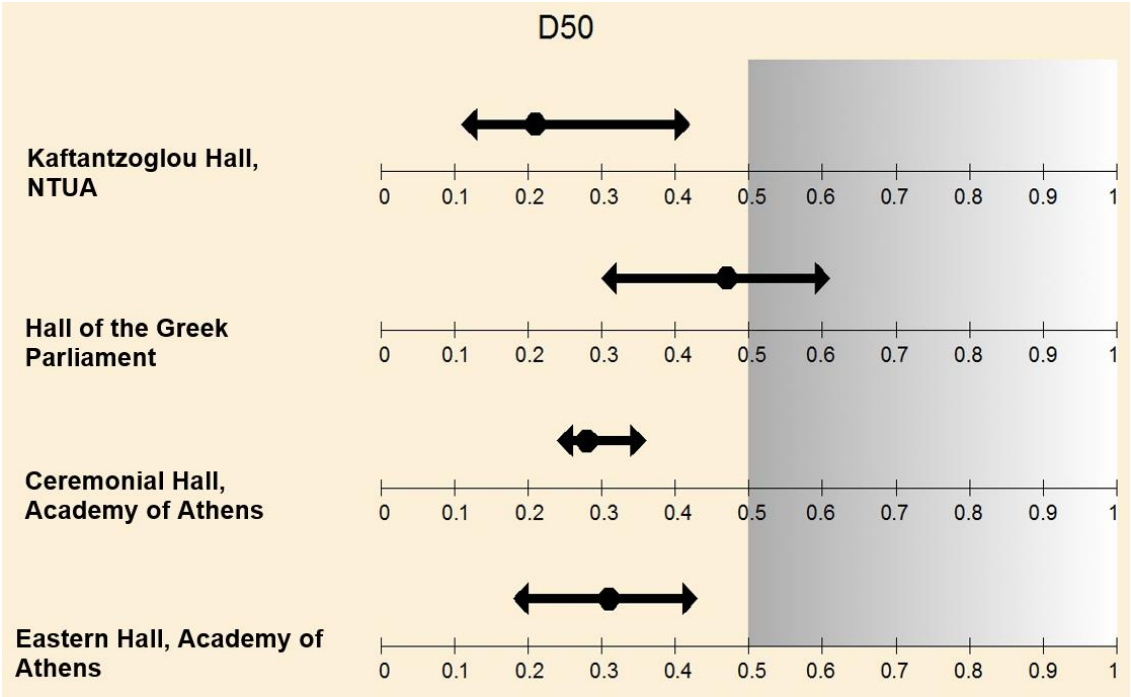

Figure 3.2 Measured Early Energy Fraction (avg. 500 Hz, 1000 Hz). Mean value [●], minimum, and maximum. The shaded region corresponds to the desired values.

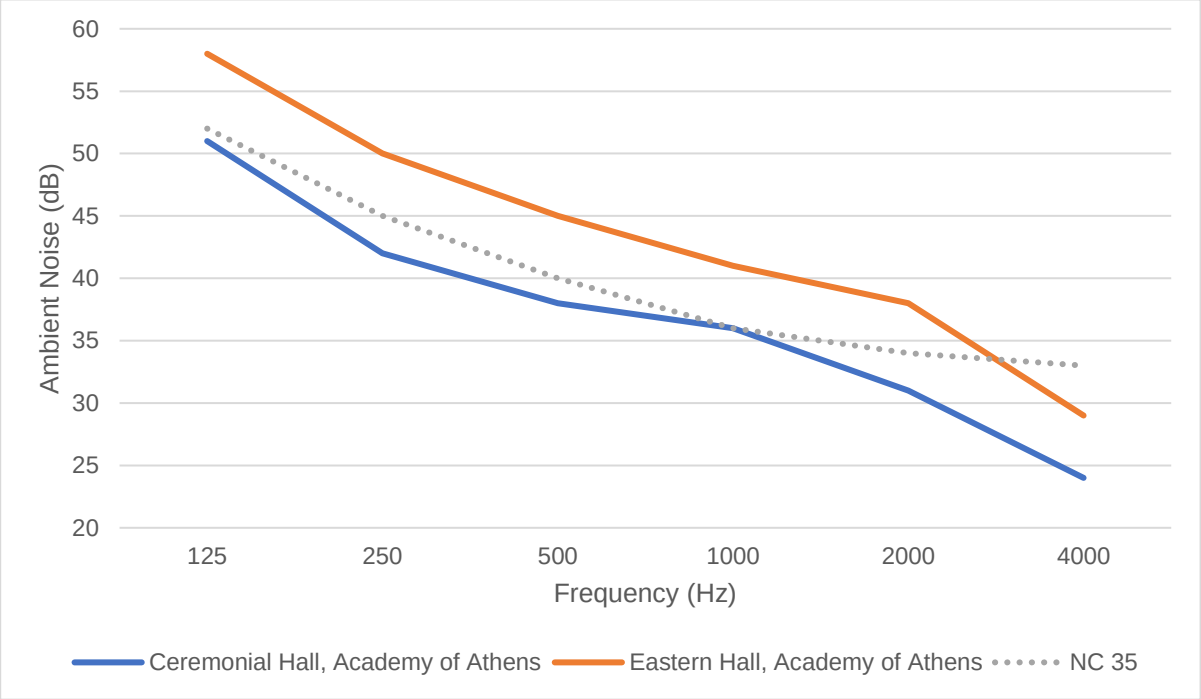

Figure 3.3 Ambient noise diagrams and desired Noise Criterion (NC35)

4 SOLUTIONS AIMING TO IMPROVE THE ACOUSTICS OF NEOCLASSICAL AUDITORIA

Given the limitations mentioned in the introduction above, the remedial acoustic intervention is based almost exclusively on the use of sound-absorbing materials. The surfaces are selected in order to control the reverberation time, and to eliminate potential echo and focusing phenomena. This approach is particularly feasible today, even in highly decorated spaces thanks to advanced sound-absorbing materials.

An example of an application is the Ceremonial Hall of the Academy of Athens, which despite the extensive frescoes that adorn it, is going to be invested, thanks to the transparency that characterizes a certain type of sound-absorbing material (Fig. 2.2). Another example is the application of sound-absorbing material on a dome ceiling, which has been proposed for the Kaftantzoglou Hall of the National Technical University of Athens. Sound-absorbing coating will be used in spray form on a blanket of rock wool, given that the market is able to promise satisfactory application of the layer to the sensitivity of the curvature (Fig. 2.1).

Although it has a beneficial role in the control of reverberation, sound absorption is known to be introduced sparingly in audience rooms due to the reduction in sound level that it causes. However, this cannot obviously be followed in the present category of rooms; therefore, in addition to the correction of the natural acoustics, the electroacoustic reinforcement of the level of the natural sound is necessary. Alternatively, to mitigate the dependence of the room on electroacoustics, it is possible to place a reflector above the speaker where it is in accordance with the architectural design of the space.

5 CONCLUSIONS

Acoustic problems in neoclassical lecture halls were highlighted using four examples of such halls in Athens. Despite the positive qualities of halls in this category, acoustic measurements documented a wide range of errors, making such halls valuable as a learning tool for application. Limitations in

acoustic redesign associated with the historical character of the halls are recognized. It is proposed through applications that the limitations can be mitigated thanks to flexible acoustic materials of advanced technology. Electroacoustics is considered an essential complement to remedial design.

6 REFERENCES

1. J. Karagiannis, H. Perdicari, G. Poulakos, A. Sotiropoulou, Remedial Acoustics of a Monumental Neoclassical Auditorium at Tech. Univ. Athens, in 9th International Conference on Auditorium Acoustics, IOA 37(3), 421-430 (2015)

2. A. Sotiropoulou, Acoustic Design of Auditoria (in Greek), Undergraduate Textbook, Kallipos Hellenic Association of Academic Libraries, Athens (2016) https://hdl.handle.net/11419/5850