

Acoustical evaluation of five public spaces in Dubrovnik

Marko Horvat, Kristian Jambrošić, Hrvoje Domitrović, Antonio Petošić

University of Zagreb, Faculty of Electrical Engineering and Computing,
Unska 3, 10 000 Zagreb, Croatia, E-Mail: marko.horvat@fer.hr

Introduction

Dubrovnik has a unique history as an independent republic of sea-conquering traders that had endured for centuries and fought all perils, from enemies to natural disasters. The heritage of its glorious past has a magnetic appeal for visitors, who come in large numbers to admire its beauty. As a part of the program for visitors, various cultural events are organized, such as concerts, theatre plays, recitals, movie screenings, book presentations, folk dancing and modern dancing shows, etc, with Dubrovnik Summer Festival as the key event of the year, when the entire city serves as one large open scene. These events take place in public spaces, some of which belong to priceless cultural treasure of Dubrovnik, dating back over 500 years. The question that is often raised is how suitable these spaces are for the cultural program they host, from the acoustical point of view. To try to give an answer to this question, five of the most representative spaces have been chosen for acoustical evaluation, with the goal of providing some guidelines for the event organizers concerning the types of events each space is suitable for. The input parameters for evaluation were reverberation time RT_{60} , early decay time EDT , clarity C_{50} and C_{80} , strength G , lateral fraction LF_E , binaural quality index BQI , speech transmission index STI , initial time delay gap $ITDG$, and specific volume V/N , where N is the number of seats. Acoustical properties of each space were evaluated according to several different criteria [1-5], and recommendations were given for possible improvements of acoustic situation, if necessary and/or possible.

Investigated spaces

As stated before, five spaces were chosen for investigation. Their interior is shown on the photos in Figure 1.

The Rector's Palace served as the administrative headquarters of Republic of Dubrovnik for centuries. Dating back to the 13th century, it has survived several disasters in the past, only to be rebuilt and restored again and again. Today it represents one of the most significant architectural monuments on Croatian coast. Its atrium often hosts classical music performances, making it interesting for the investigation. The atrium holds 300 visitors on the ground floor and the balcony, and has a total volume of 2900 m³.

Revelin Fortress is a shining example of defence architecture, built in the 15th century to help protect Dubrovnik from enemy attacks, as a direct result of the political situation of the time. After the catastrophic earthquake in 1667 the fortress became the municipal headquarters of the Republic, hosting the state and the cathedral treasuries. Today its terrace hosts theatre plays within Dubrovnik Summer Festival, and various concerts are organized in the interior. The interior is divided into three

major parts with the total volume of 5300 m³. Only one of these three parts is usually used for concerts, with a volume of 1500 m³ and 220 seats.

Slanica Concert Hall is used by Dubrovnik Symphony Orchestra. In the past it was used only as a rehearsal space, but in the absence of a proper concert hall, concerts are held there as well. With a volume of only 685 m³, it seats 170 visitors, both on the ground floor and the balcony.

Marin Držić Theatre is a part of the long tradition of theatre performances in Dubrovnik staged both indoors and outdoors. Over the course of history, the theatre has changed its name and location on several occasions. At present, it bears the name of one of the most famous Croatian writers, who lived in Dubrovnik in the 16th century. The building that hosts the theatre today was built in the second half of the 19th century, with a volume of 1640 m³ and 283 seats.

Sloboda Movie Theatre is intended primarily for movie screenings. Recent restoration work included both the changes in interior design and the modernization of the audio-visual reproduction system. The volume of the theatre is 1350 m³, while the number of seats has been reduced during the restoration process, from the initial 273 to 175 it has today.

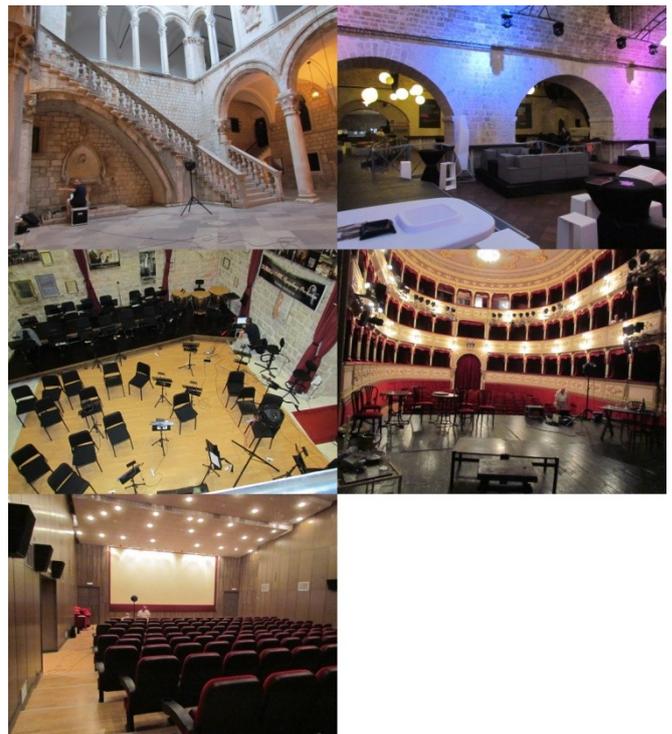


Figure 1: Investigated spaces: the atrium of the Rector's Palace (top left), Revelin Fortress (top right), Slanica Concert Hall (mid left), Marin Držić Theatre (mid right), and Sloboda Movie Theatre (bottom left)

Measurement results and evaluation

The measurements were made over the course of three days with a measurement setup that consisted of a laptop computer and software capable of measuring impulse responses by means of the integrated impulse response method. An omni-directional sound source that meets the requirements in [1] was used together with a microphone with polar pattern interchangeable between omni-directional and figure-of-eight (necessary for LF_E measurements). For measurements of BQI , an in-ear microphone pair Sound Professionals SP-TFB-2HT was used together with a portable recorder M-audio Microtrack II as a preamplifier. The person wearing the microphones was instructed on how to behave during the measurements.

The summary of the results is shown in Table 1 for all five investigated spaces. The usability of these spaces is evaluated regarding their primary purpose. The values in Table 1 are coloured according to their suitability for a given purpose, specifically, red-coloured values as unsuitable, yellow-coloured ones as borderline suitable, green-coloured as suitable and black-coloured were not considered for a particular space and purpose.

Table 1: Single-number values of relevant parameters obtained at all five locations.

	Rector's Palace	Revelin Fortress	Slanica Concert Hall	Marin Držić Theatre	Sloboda Movie Theatre
RT_{60} (s)	3.80	1.34	1.20	0.78	1.06
EDT (s)	3.72	1.30	1.20	0.72	0.94
C_{50} (dB)	-8.1	-1.3	-1.3	2.1	0.1
C_{80} (dB)	-5.5	1.6	1.6	5.9	3.6
G_{mid} (dB)	7.0	0.7	5.7	1.6	4.6
LF_E	0.20	0.10	0.23	0.12	0.13
BQI	0.74	0.63	0.72	0.71	0.75
STI	0.36	0.58	0.56	0.68	0.65
$ITDG$ (ms)	24.50	2.56	3.74	4.20	4.38
V (m ³)	2900	1500	685	1640	1350
N	300	220	170	283	175
V/N (m ³)	9.7	6.8	4.0	5.8	7.7

The Rector's Palace, i.e. its atrium is intended primarily for performances involving classical symphonic and chamber music. Despite the fact that it is not a closed space, the reverberation time is excessively high, and considerably higher than required for this type of music. It should, however, be noted that the measurements in all five spaces were conducted in the unoccupied state. Therefore, it is reasonable to expect that the acoustical conditions in the occupied state will be more favourable in this case. The values of other parameters fall within the range recommended for this type of performance.

The Revelin Fortress hosts modern music events, i.e. concerts with both vocal and instrumental performance, aided by modern-day sound systems and electronic equipment. Although the entire interior is made of stone, the installed furniture and decorative elements hanging from the ceiling provide considerable acoustical damping. It is interesting to note that the measurement results suggest that the acoustical conditions in this space are suitable for opera

performances, although the space itself could not handle such an event. With people present, acoustical conditions in the space become even more favourable for the usual types of performances.

Concert Hall Slanica could be used for chamber music performances, provided that the reverberation time is increased by appropriate measures. However, the crucial problem of too small a volume, and, consequently, too small specific volume, still remains, basically rendering this particular hall unusable for both symphonic and chamber music.

Acoustical conditions in Marin Držić Theatre are quite appropriate for speech-based events, primarily for theatre plays. Specific volume exceeds the recommended values due to the rather high ceiling. The values of reverberation time and speech intelligibility allow the theatre to be used as an auditorium, if necessary.

Finally, Sloboda Movie Theatre in its present state could be used as a theatre or an auditorium, given the values of reverberation time and speech intelligibility. However, if it is to be used as a movie theatre, the reverberation time should be reduced to half its present value. As the walls are already fairly absorptive, the ceiling and the floor can receive additional treatment to meet this requirement.

Conclusions

As most of the investigated spaces were not built for the purpose they serve now, it is not plausible to expect that the acoustical conditions in these spaces will be appropriate for that purpose. In some of these spaces it is possible to achieve certain improvement with only minor interventions, whereas the others are simply inappropriate for the events that take place in them. Since the evaluation described in this part has been made in the unoccupied state, a certain improvement is already gained with people present. Nevertheless, these venues, along with many others in Dubrovnik, have a historical appeal that makes the experience of witnessing a cultural event in such a place a unique one.

Acknowledgements

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