ACOUSTICAL SUITABILITY OF HISTORIC SPACES AS VENUES FOR MODERN-DAY EVENTS

Kristian Jambrošić, Marko Horvat, Hrvoje Domitrović, Antonio Petošić

University of Zagreb, Faculty of Electrical Engineering and computing, Unska 3, 10 000 Zagreb, Croatia,
Email: kristian.jambrosic@fer.hr.

ABSTRACT

Historic spaces with great architectural significance are often used as venues for different kinds of events that tend to enrich the cultural life of a modern city. Built in old city cores, often with considerable restrictions on space, they performed different functions throughout the history of a city, none of which can be connected with their current use in any reasonable way. Therefore, the question is raised about the suitability of such spaces in the acoustical sense for the events they host today. To investigate this, a case study was made in four public spaces located in the city of Dubrovnik, with its old city as a crown jewel of Croatian coast with shining examples of civil and military architecture, and also as a centre of rich cultural life that comes to its peak during high season in the summer. The four selected spaces include a historic municipal headquarters, a fortress, a historic theatre and an improvised concert hall. The assessment of their acoustical suitability was carried out through measurements of their impulse responses and calculation of the usual objective parameters: reverberation time, early decay time, binaural quality index, strength, clarity, initial time delay gap, speech transmission index and specific volume per person. Several different criteria were then applied to determine the extent to which individual spaces were suitable not only for their primary purpose, but also for other potential uses. Based on the results, recommendations were given for possible improvements of acoustic situation in specific spaces, but such improvements are not likely to be implemented due to the strict rules on preservation of historical buildings.

INTRODUCTION

Dubrovnik is the biggest city of the southeast part of Croatia's costal region at the Adriatic Sea, with a unique history and architecture. It was an independent republic based on maritime trade, particularly during the 15th and 16th century. Many important monuments exist in the old city, with great historical and cultural importance. For this reason, it is declared as a UNESCO World Heritage Site. UNESCO describes Dubrovnik with the following words: “The 'Pearl of the Adriatic', situated on the Dalmatian coast, became an important Mediterranean naval power from the 13th century onwards. Although severely damaged by the earthquake of 1667, Dubrovnik managed to preserve its beautiful Gothic, Renaissance and Baroque churches, monasteries, palaces and fountains. Damaged again in the 1990s in armed conflict, it is now the focus of a major restoration program coordinated by UNESCO.” [1]. The heritage of its glorious past has still 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 throughout the year, such as concerts, theatre plays, recitals, movie screenings, book presentations, folk dancing and modern dancing shows, etc, The Dubrovnik Summer Festival is the key event of the year, when the entire city serves as one large open scene. All such events take mostly place in public spaces, some of which belong to priceless cultural treasure of Dubrovnik, dating back over 500 years.

There is an ever-growing interest displayed by city municipality to use the touristic potential of the old core of Dubrovnik. The suitability of all the important historical sites for their present purpose and other possible applications has been considered, especially from the acoustical point of view. For this reason, the authors of this paper got the task to evaluate the acoustical suitability of four of the most representative spaces, with the goal of providing some guidelines for the event organizers concerning the types of events each space is suitable for.

For the purpose of evaluation, the following room acoustic parameters were chosen: 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 in a typical seating layout in each venue. Acoustical properties of each space were evaluated according to several different criterions [2-6] as there are no unique guidelines and/or standards that are widely recognized by acousticians to provide the optimal range of all considered parameters and for all possible uses of the spaces.

After the measurements were conducted, recommendations were given for possible improvements of acoustic situation if necessary, as well as an evaluation if those sites could be used also for other purposes in terms of their acoustical suitability. A novel evaluation chart for comparison the acoustical suitability of spaces was introduced and applied.

INVESTIGATED VENUES

Four of the most frequently used venues for cultural events in Dubrovnik were chosen for investigation.

First venue was the Rector's Palace that served as the administrative headquarters of the 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 [7]. Today it represents one of the most significant architectural monuments on Croatian coast. Its atrium, open to the sky, often hosts classical music performances, making it interesting for the investigation. The atrium holds typically up to 300 visitors on the ground floor and the balcony, and has a total volume of 2,900 m^3. For special events, the number of seats can be increased to twice the typical number. The acoustical image of the stage differs very much depending on the position of the musicians. Its interior is shown in Figure 1.

Figure 1. The atrium of the Rector's Palace. Usual location of the musicians (top), with the 1st floor balcony just visible on the top of the picture; the rear part of the atrium (bottom) with the space usually occupied by the audience, and the ground floor gallery.

The second venue was the Revelin Fortress, 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 space on the first floor is divided into three major

interconnected parts with the total volume of 5,300 m^3. The venue is nowadays used as a music club for young visitors with a dance floor and seating areas. Although the measurements were done in full space, only one part of this three-part space could be used for concerts, with a volume of 1,500 m^3 and 220 seats. The venue is represented in Figure 2.

Figure 2. Interior of the Revelin Fortress. The centre part of the interior three-part space (top) used as a dance floor; the lateral part of the interior with three solid walls and the fourth arched wall towards the rest of the interior space, suitable for concert events.

The third venue was the Slanica Concert Hall used by the 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 m^3, it seats 170 visitors, both on the ground floor and the balcony. It is interesting to mention that the musicians like the acoustic behaviour of the space because of the vicinity of hard, reflexive walls around the orchestra position, Figure 3.

Figure 3. Slanica concert hall. Plan view of the concert hall from the balcony (top), only the main area for the symphonic orchestra can be seen; the rear part of the concert hall reserved for few listeners (bottom), and the balcony opening at top left of the picture.

Finally, the fourth venue was the Marin Držić Theatre, as 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 1,640 m^3 and 283 seats, Figure 4.

RESULTS AND EVALUATION OF THE ACOUSTIC SUITABILITY

Acoustical measurements were made over the course of three days with a measurement setup that consisted of a laptop computer and the EASERA software [8] capable of measuring impulse responses

by means of the integrated impulse response method. An omni-directional sound source that meets the requirements in [2] 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.

Figure 4. Marin Držić Theatre. The stage (top) seen from the audience; view from the stage to the audience area (bottom), with the three levels of balconies.

The summary of measurement results is shown in Table 1 for all four investigated venues. The usability of these spaces regarding their acoustic performance is evaluated regarding their primary purpose. The values in Table 1 are coloured according to their suitability for a given purpose. Red-coloured values are considered as unsuitable, yellow-coloured ones as borderline suitable, green-coloured as suitable and black-coloured were not considered for a particular space and purpose. The ranges of suitability for particular parameters were defined from recommendations found in [2-6].

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

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

The Rector's Palace, i.e. its atrium is intended primarily for performances involving classical symphonic and chamber music. The frequency dependent reverberation time is shown in Figure 5. Despite the fact that it is not a closed space, the reverberation time is excessively high, considerably higher than required for this type of music. It should, however, be noted that the measurements in all four spaces were conducted in the unoccupied state. Therefore, it is to be expected 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. Table 2 shows the suitability of this venue for other purposes in terms of its acoustic properties.

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. The frequency dependent reverberation time is shown in Figure 6. Although the entire interior is made of stone, the installed furniture and decorative elements hanging from the ceiling provide considerable acoustical damping.

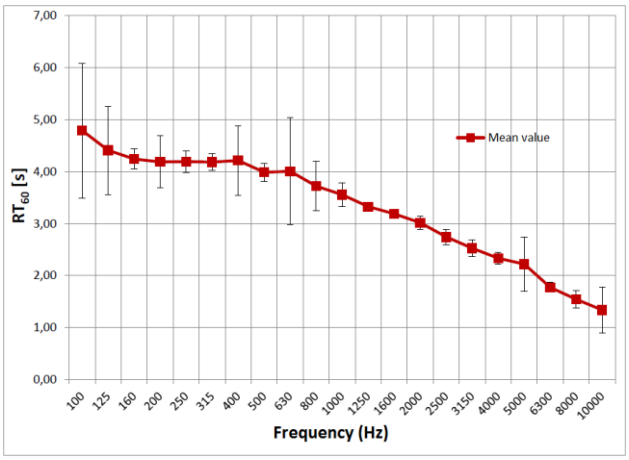

Figure 5. Mean RT_{60} of the Rector's Palace for third-octave frequency bands from 100 to 10000 Hz.

Table 2. The suitability of the Rector's Palace for various purposes based on the mean values of typical acoustic parameters.

The Rector's Palace	RT_{60} (s)	EDT (s)	BQI	G_{mid} (dB)	C_{80} (dB)	ITDG (ms)	V/N (m^3/pers.)	STI
Measured values	3.80	3.72	0.74	7.0	-5.5	24.50	9.7	0.36
Symphonical music								
Chamber music								
Opera								
Speech								
Cinema								

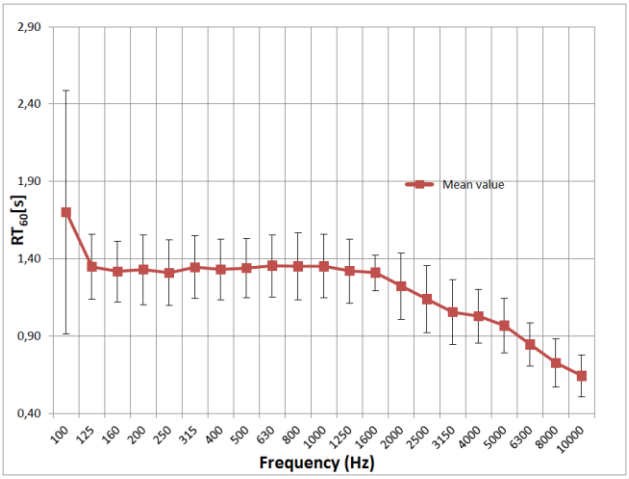

Figure 6. Mean RT_{60} of Revelin Fortress for third-octave frequency bands from 100 to 10000 Hz.

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. Table 3 shows the suitability of this venue for other purposes.

Table 3. The suitability of Revelin Fortress for various purposes based on the mean values of typical acoustic parameters.

Revelin Fortress	RT_{60} (s)	EDT (s)	BQI	G_{mid} (dB)	C_{80} (dB)	ITDG (ms)	V/N (m^3/pers.)	STI
Measured values	1.34	1.30	0.63	0.7	1.6	2.56	6.8	0.58
Symphonical music								
Chamber music								
Opera								
Speech								
Cinema								

The Slanica Concert Hall could be used for chamber music performances, provided that the reverberation time is increased by appropriate measures. However, the crucial problem of this particular venue is its too small volume, and, consequently, too small specific volume, basically rendering this particular hall unusable for both symphonic and chamber music. The frequency dependent reverberation time is shown in Figure 7. Table 4 shows the suitability of this venue also for other purposes.

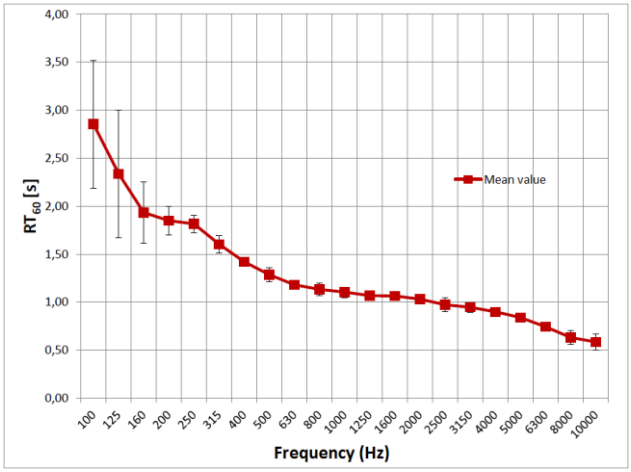

Figure 7. Mean RT_{60} of Slanica Concert Hall for third-octave frequency bands from 100 to 10000 Hz.

Acoustical conditions in the Marin Držić Theatre are quite appropriate for speech-based events, primarily for theatre plays. This is of course expected given the highly sound absorbing interior of the theatre. The frequency dependent reverberation time is shown in Figure 8. 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. Table 5 shows the suitability of this venue also for other purposes.

Table 4. The suitability of Slanica Concert Hall for various purposes based on the mean values of typical acoustic parameters.

Slanica Concert Hall	RT_{60} (s)	EDT (s)	BQI	G_{mid} (dB)	C_{80} (dB)	ITDG (ms)	V/N (m^3/pers.)	STI
Measured values	1.20	1.20	0.72	5.7	1.6	3.74	4.0	0.56
Symphonical music								
Chamber music								
Opera								
Speech								
Cinema								

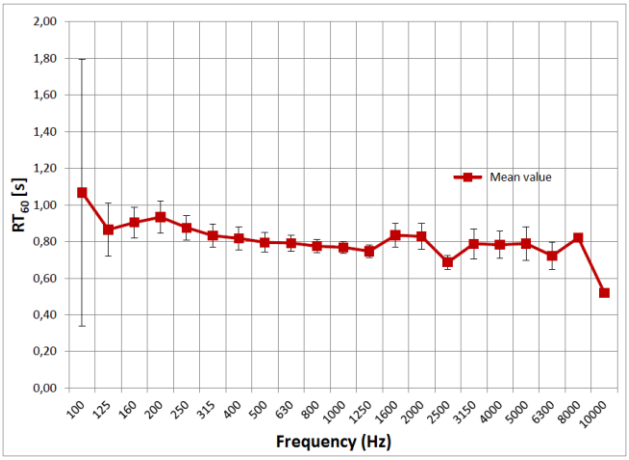

Figure 8. Mean RT_{60} of Marin Držić Theatre for third-octave frequency bands from 100 to 10000 Hz.

Table 5. The suitability of Marin Držić Theatre for various purposes based on the mean values of typical acoustic parameters.

Marin Držić Theatre	RT_{60} (s)	EDT (s)	BQI	G_{mid} (dB)	C_{80} (dB)	ITDG (ms)	V/N (m^3/pers.)	STI
Measured values	0.78	0.72	0.71	1.6	5.9	4.20	5.8	0.68
Symphonical music								
Chamber music								
Opera								
Speech								
Cinema								

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 necessarily appropriate for that purpose. In some of these spaces it is possible to achieve certain improvement with only minor interventions, whereas others are simply inappropriate for the events that take place in them. Due to the historical significance of these venues, major interventions that would permanently change their interior are not allowed by historians and conservators. The only option that usually remains is to attempt to improve the acoustic situation through temporary installations that can be removed easily without causing damage.

Since all measurements and evaluations described in this paper have been made with the venues in the unoccupied state, a certain improvement is already gained with people present, which is especially true for the Rector's Palace that consists entirely of hard, reflecting surfaces with the exception of a perfectly absorptive ceiling. 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.

A question that asserted itself is how to establish the evaluation criteria for spaces that primarily host speech-based events, regarding the speech intelligibility. In a usual situation the criteria in relevant literature are quite satisfactory. However, in a specific situation such as this one, the events are visited by a multi-lingual audience consisting mostly of non-native speakers. Therefore, the authors believe that the requirements from relevant literature should be made even stricter in terms of further reduction of reverberation time in order to improve speech intelligibility.

For the purpose of evaluating the acoustic suitability of the investigated spaces, a novel approach has been proposed. Various recommendations found in the literature, such as [2-6], were unified in one table with colour-coded suitability marks (red for unsuitable, yellow for borderline suitable and green for suitable), as shown in Tables 2-5. The authors believe that such a representation of measured values against typical acoustical uses of a venue represents a simple way of showing the suitability of this venue for a certain type of event. Such a display is invaluable for non-acousticians who have trouble interpreting the numerical values of the acoustical parameters and grasping their meaning for a given venue. Moreover, such a representation can help the local municipality to make decisions on possible use of a venue, historic or otherwise.

ACKNOWLEDGEMENT

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