



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

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Content

- Introduction
- Investigated spaces with measurement results and evaluation
- Conclusions

Introduction

- Dubrovnik - an independent republic based on maritime trade, particularly during the 15th and 16th century
- UNESCO World Heritage Site:
- “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.



Introduction

- diverse cultural program for visitors → Dubrovnik Summer Festival
- venues = historic spaces of great significance + modern-day buildings
- acoustical suitability of the venues for the foreseen applications
- 5 venues chosen for evaluation
- RT_{60} , EDT , C_{50} , C_{80} , G , LF_E , BQI , STI , $ITDG$ and V/N

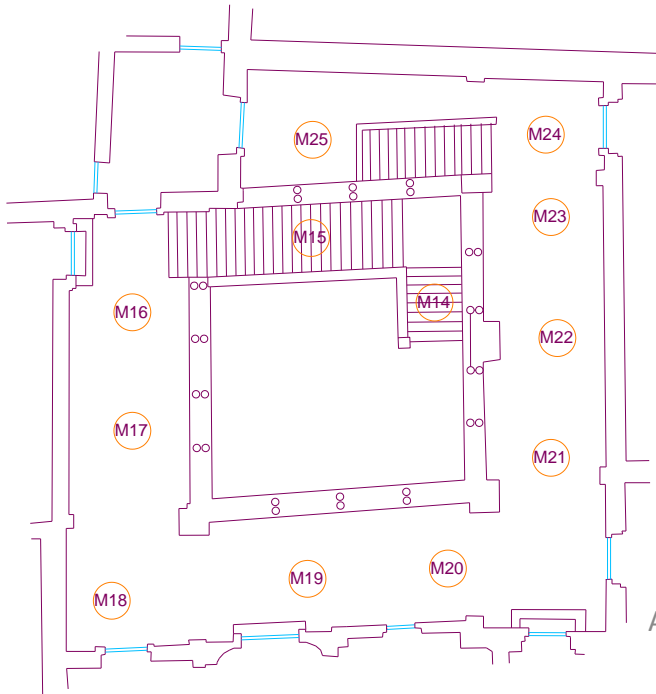
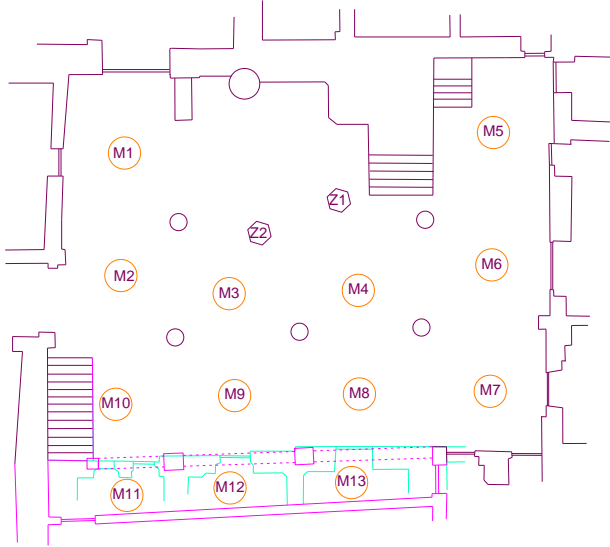


Venues - the Rector's Palace

- 13th century building
- one of the most significant architectural monuments on Croatian coast
- atrium - classical and chamber music performances
- 300 seats - ground floor and balcony
- total volume = 2900 m³

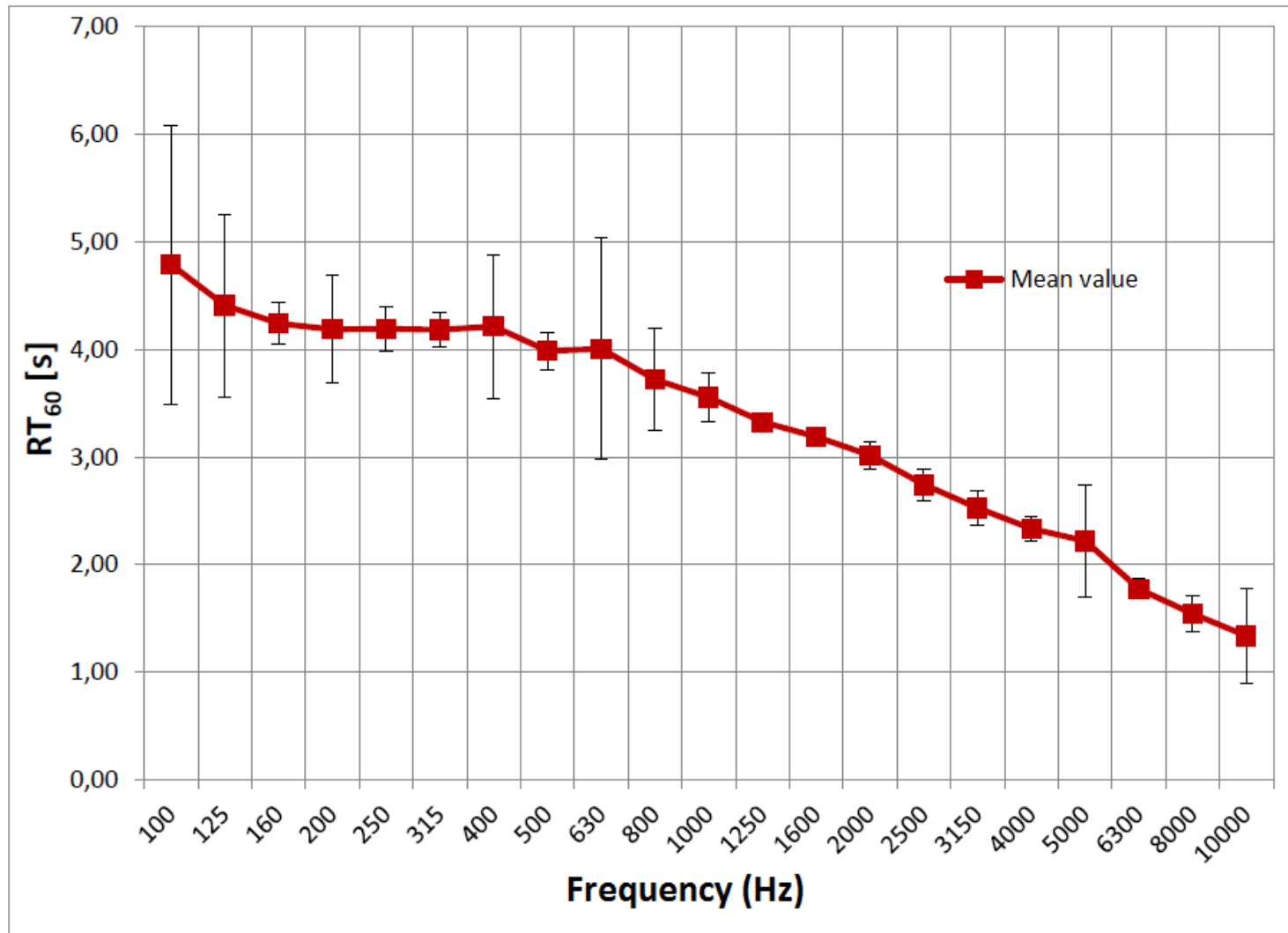


Venues - the Rector's Palace

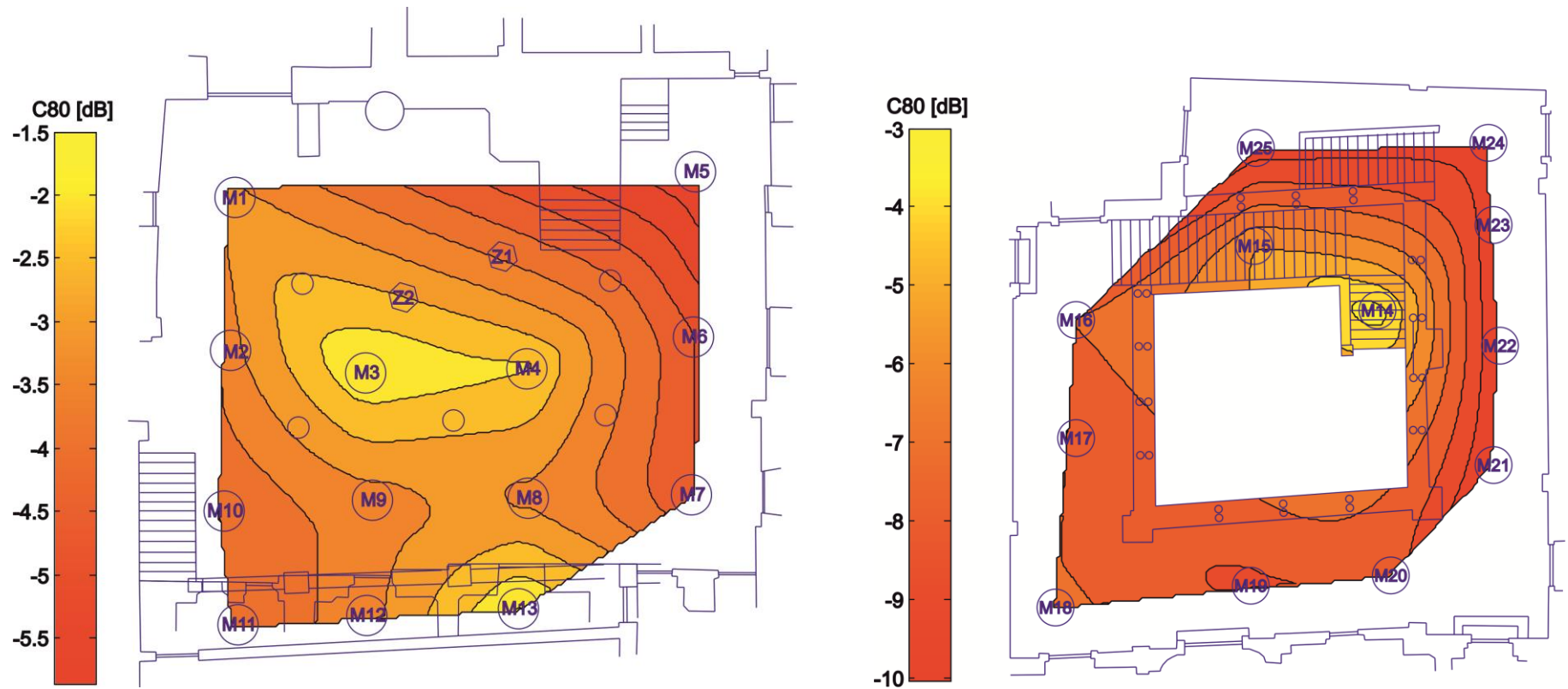


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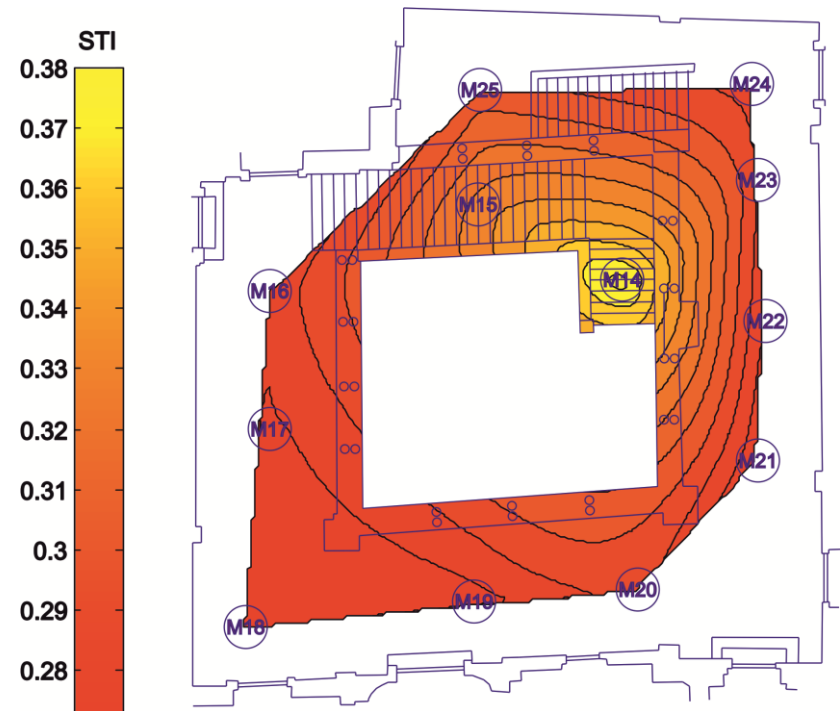
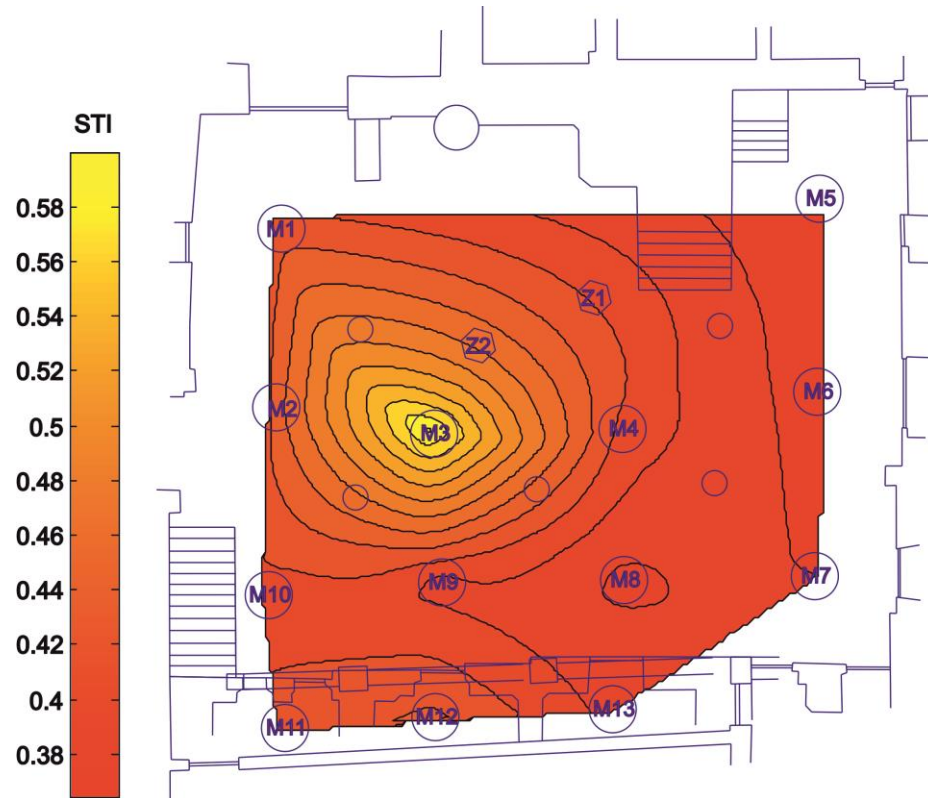
Venues - the Rector's Palace



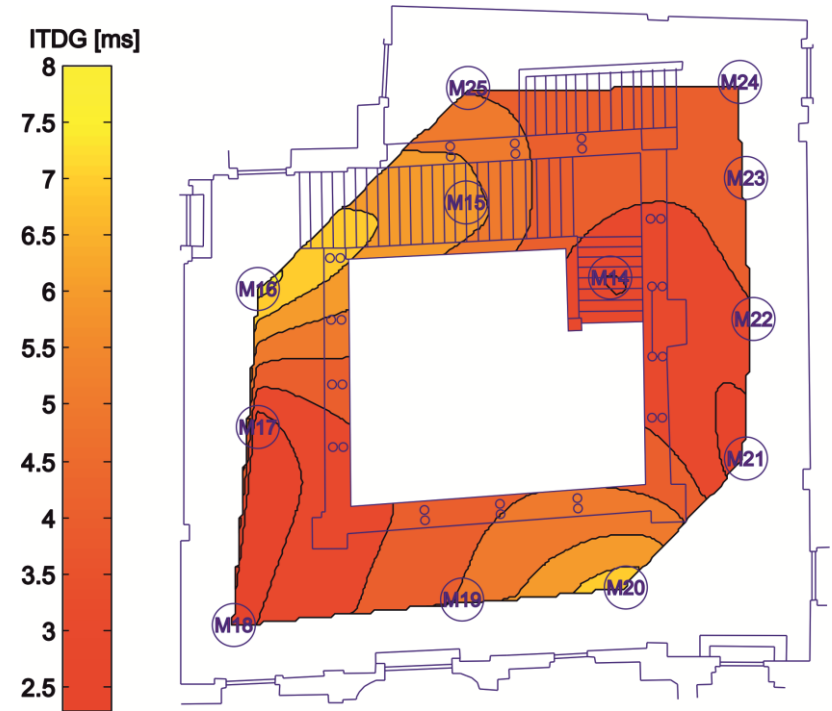
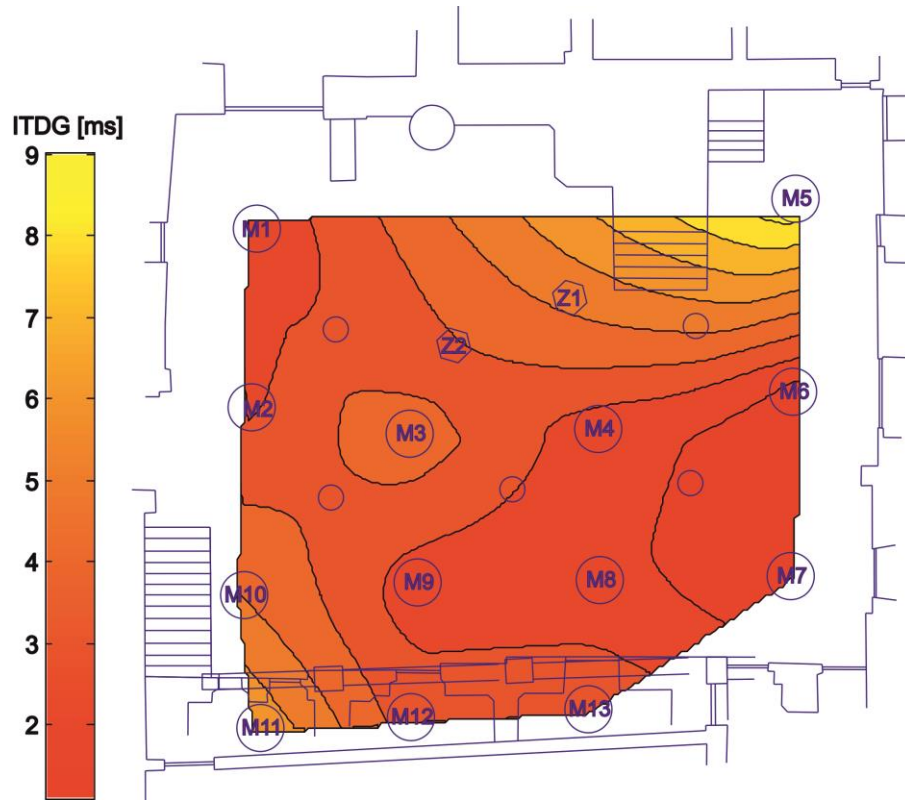
Venues - the Rector's Palace



Venues - the Rector's Palace



Venues - the Rector's Palace



Venues - the Rector's Palace

- Evaluation according to:
 - HRN EN ISO 3382-1:2010 „Measurement of room acoustic parameters -- Part 1: Performance spaces “
 - L. Beranek: „Concert halls and opera houses: music, acoustics and architecture“, Springer-Verlag 2004.
 - D. Rossing: „Springer Handbook of Acoustics“, Springer Verlag, 2007.
 - M. Long: „Architectural Acoustics“, Academic Press, 2006.

Venues - the Rector's Palace

Frequency averaged values on measuring locations for empty concert halls and multipurpose halls smaller than 25.000 m³ according to the EN ISO 3382-1:2010 norm

Acoustical parameter	Frequency (Hz)	Typical values	Knežev dvor
Gain G, dB	500 – 1000	-2 dB to +10 dB	7 dB
EDT, s	500 – 1000	1,0 s to 3,0 s	3,72 s
Clarity C ₈₀ , dB	500 – 1000	-5 dB to +5 dB	-5,5 dB
Definition D ₅₀	500 – 1000	0,3 to 0,7	0,15

Venues - the Rector's Palace

Recommended averaged values of some acoustic parameters of empty concert halls for classical music (Rossing).

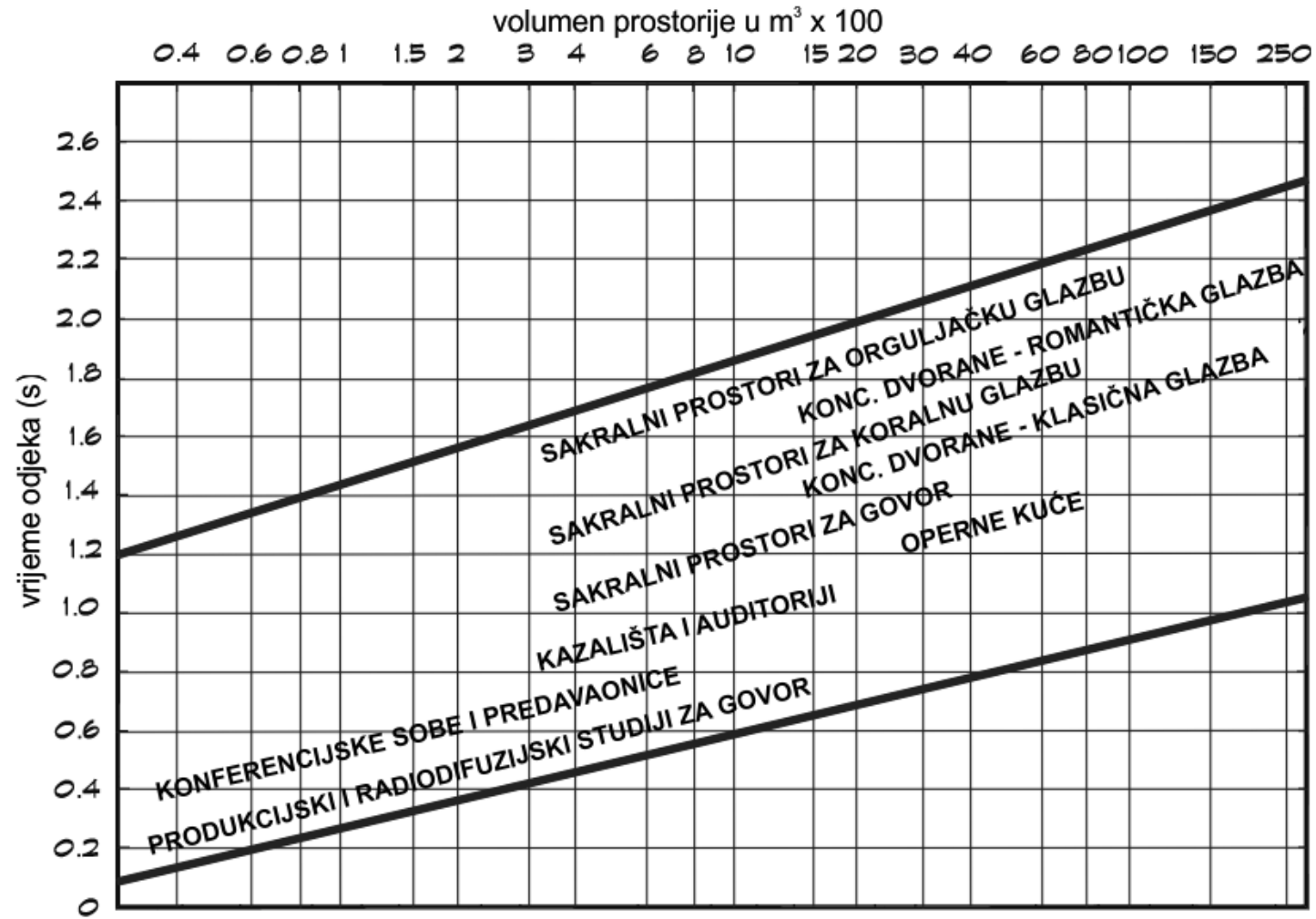
Parameter	Symbol	Chamber music	Symphonic music	Knežev dvor
Hall size	V/N	2.500 m ³ / 300 seats	25.000 m ³ / 2.000 seats	2.910 m ³ / 300 seats
Reverberation time	T	1,5 s	2,0 – 2,4 s	3,80 s
Early decay time	EDT	1,4 s	2,2 s	3,72 s
Gain	G	10 dB	3 dB	7,0 dB
Clarity	C	3 dB	-1 dB	-5,5 dB
Lateral energy fraction	LEF	0,15 – 0,20	0,20 – 0,25	0,20
Binaural quality index	1-IACC	0,6	0,7	0,74

Venues - the Rector's Palace

Optimum values for some acoustic parameters of concert halls (Beranek).

Acoustical parameter	Purpose			
	symphonic music (over 1.400 seats)	chamber music (manje od 700 seats)	opera (preko 1.200 seats)	Knežev dvor
Reverberation time RT_{60}	1,8 – 2,1 s	1,6 – 1,8 s	1,4 – 1,6 s	3,80 s
Early Decay Time EDT	2,2 – 2,6 s	1,9 – 2,3 s	1,5 – 1,9	3,72 s
Binaural Quality Index BQI	0,65 – 0,71	0,7 – 0,76	0,6 – 0,71	0,53
Gain G_{mid}	1,5 – 5,5 dB	9,0 – 13,0 dB	-1,0 – 2,0 dB	7,0 dB
Gain G_{125}	3,0 – 6,0 dB	9,0 – 13,0 dB	-1,05 – 2,3 dB	13,7 dB
Initial Time Delay Gap ITDG	< 25 ms	< 20 ms	< 23 ms	24,5 ms
Clarity C_{80}	-3,0 – 0 dB	-2,0 – 2,0 dB	1,0 – 3,0 dB	-5,5 dB

Venues - the Rector's Palace



Venues - the Rector's Palace

Intervals of the recommended hall volume per seat, depending on the purpose of the hall (Long)

Auditorium type	Volume per seat (m ³)			
	min.	mean	max.	Knežev dvor
Halls for speech	2,3	3,1	4,3	9,7
Concert halls	6,2	7,8	10,8	9,7
Opera houses	4,5	5,7	7,4	9,7
Churches, sacral spaces	5,1	7,2	9,1	9,7
Multifunctional auditorium	5,1	7,1	8,5	9,7
Cinemas	2,8	3,5	5,1	9,7

Venues - the Rector's Palace

Estimation of speech intelligibility depending on the number value of the STI parameter.

Speech intelligibility evaluation	STI
very bad	$< 0,32$
bad	$0,32 - 0,45$
average	$0,45 - 0,60$
good	$0,60 - 0,75$
excellent	$> 0,75$

Venues - the Rector's Palace

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								

Venues - Revelin Fortress

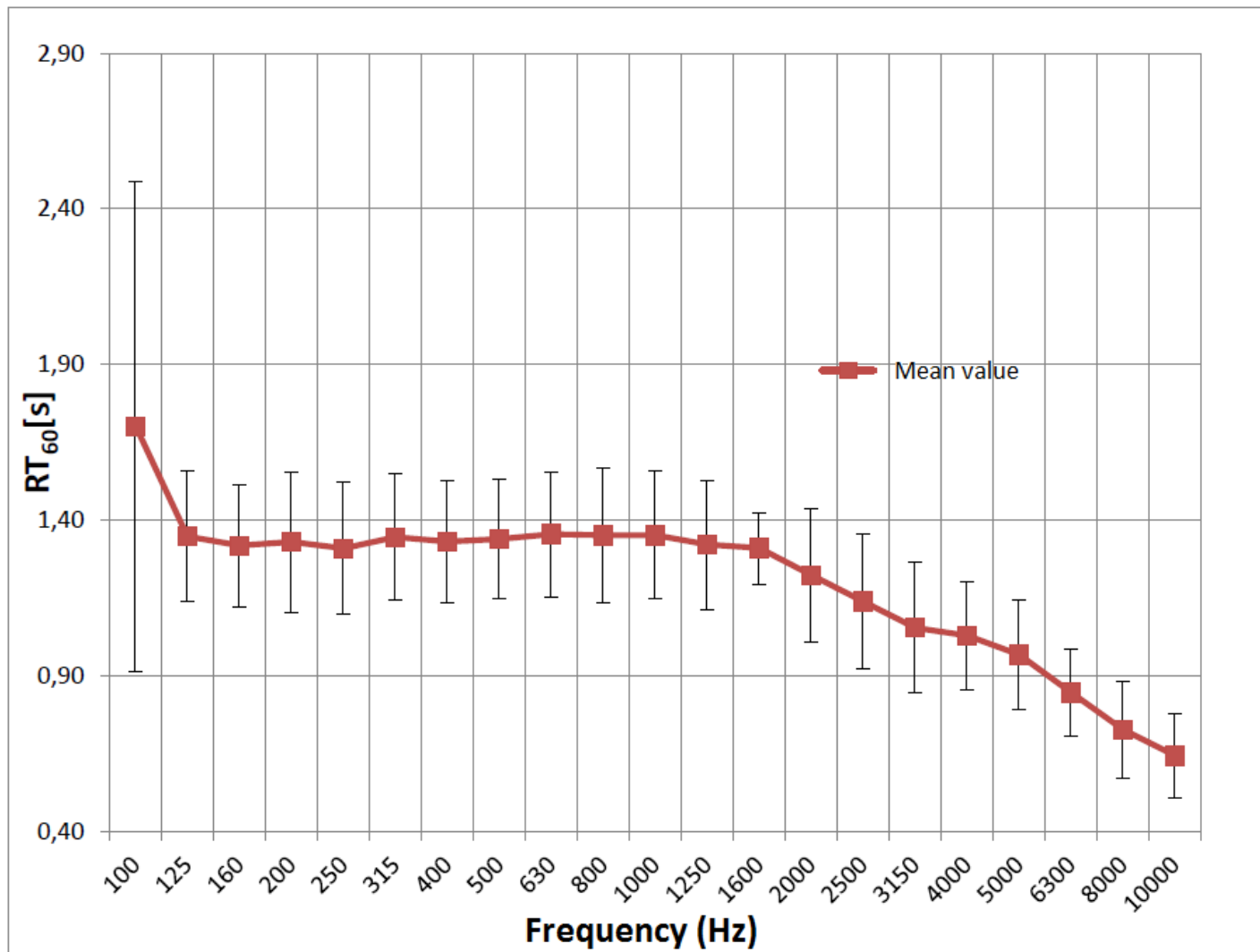
- 15th century
- fortification, treasury, municipal headquarters
- terrace - summer theatre
- interior - modern concerts
- volume = 1500 m³
- 220 seats



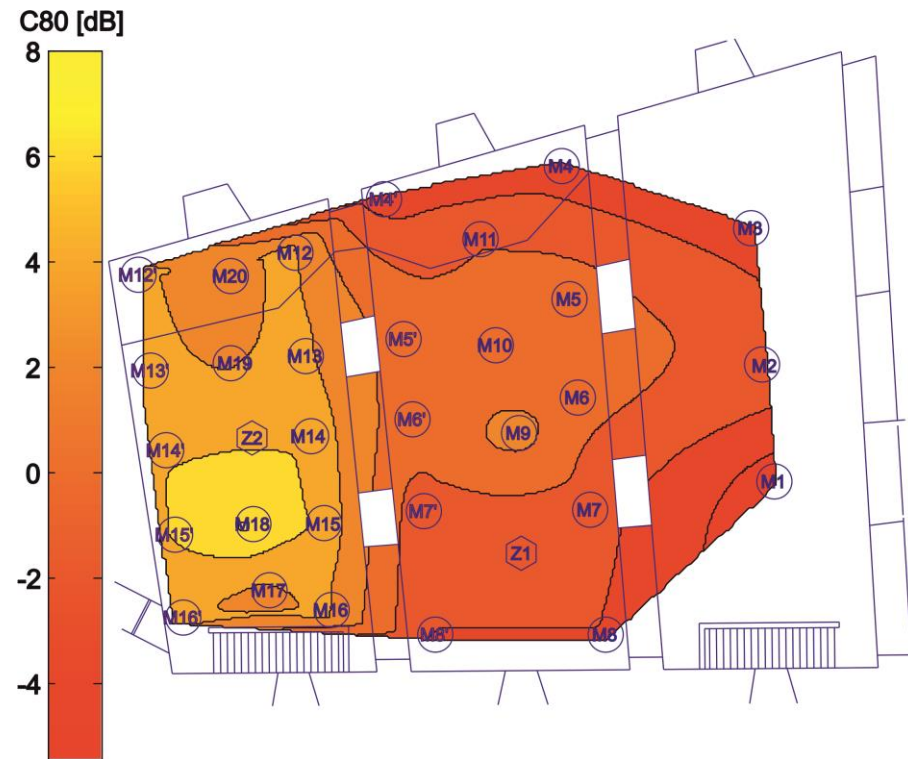
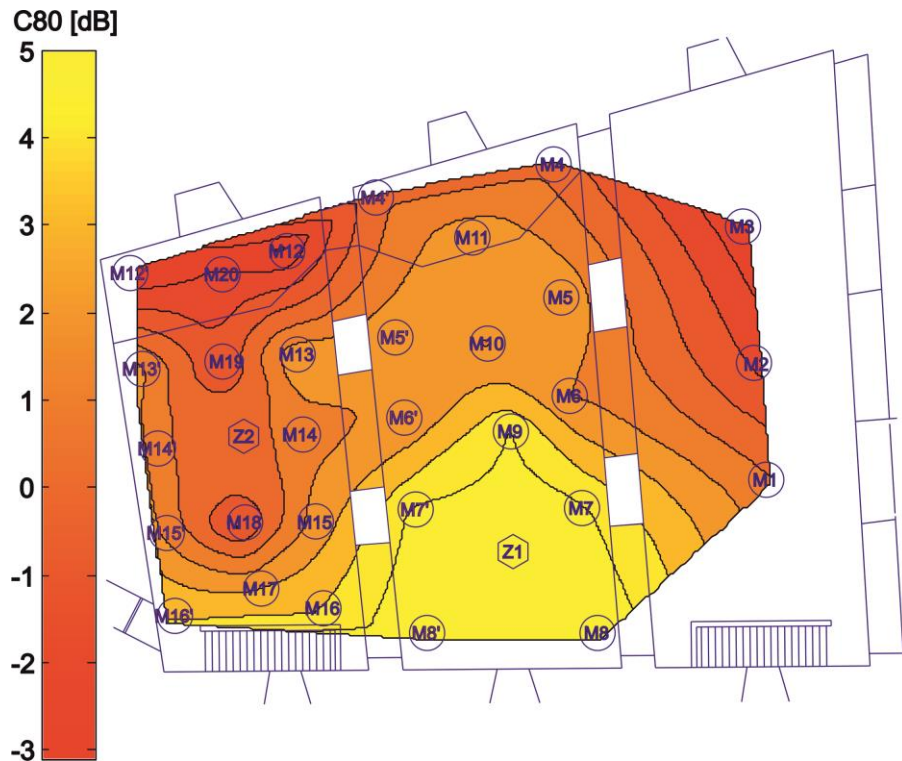
Venues - Revelin Fortress



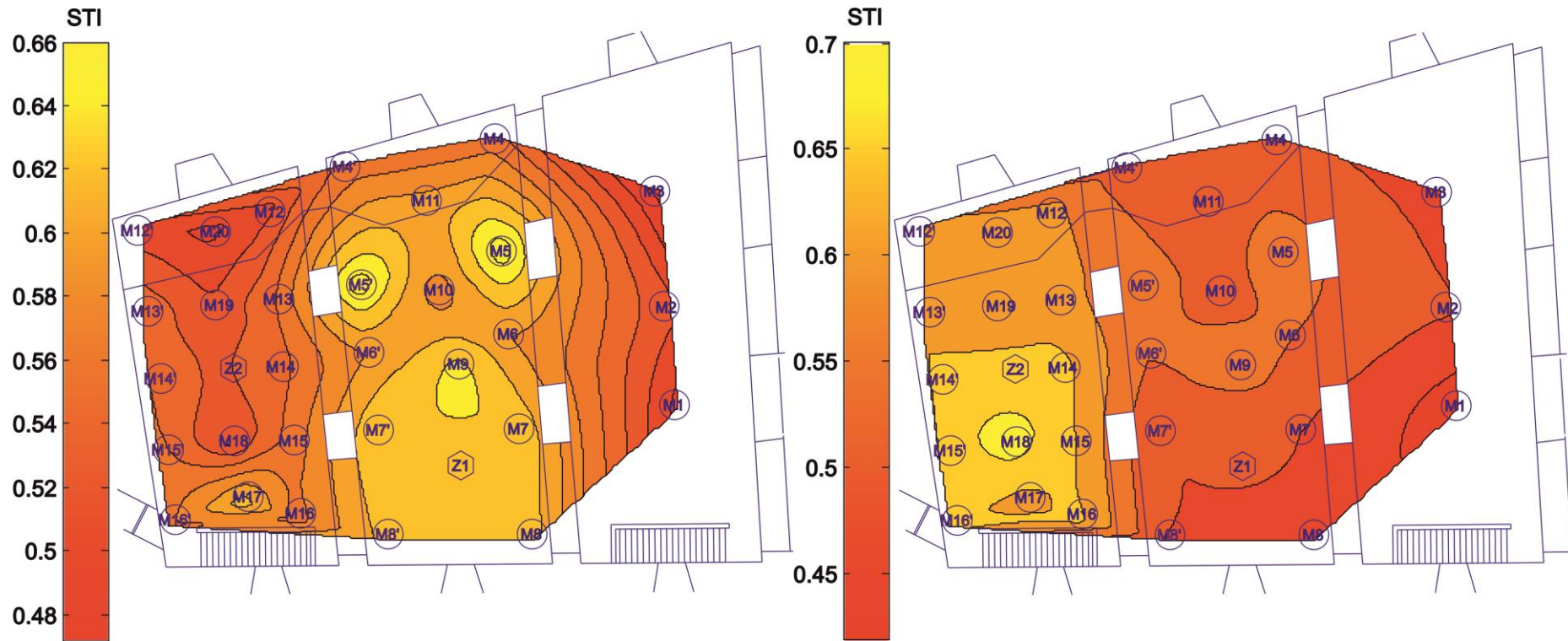
Venues - Revelin Fortress



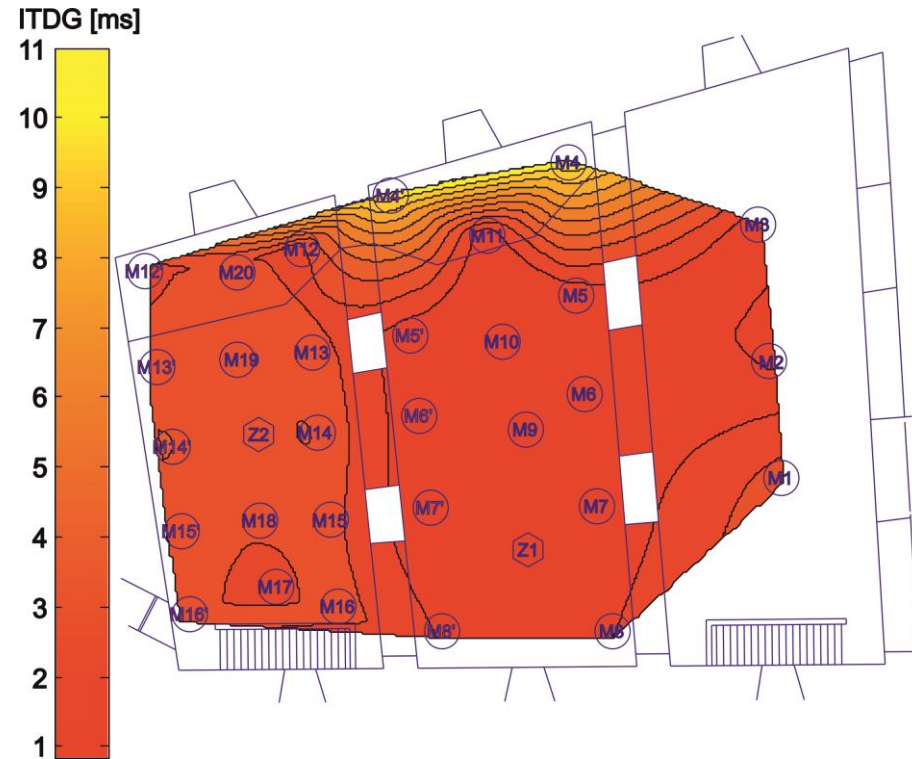
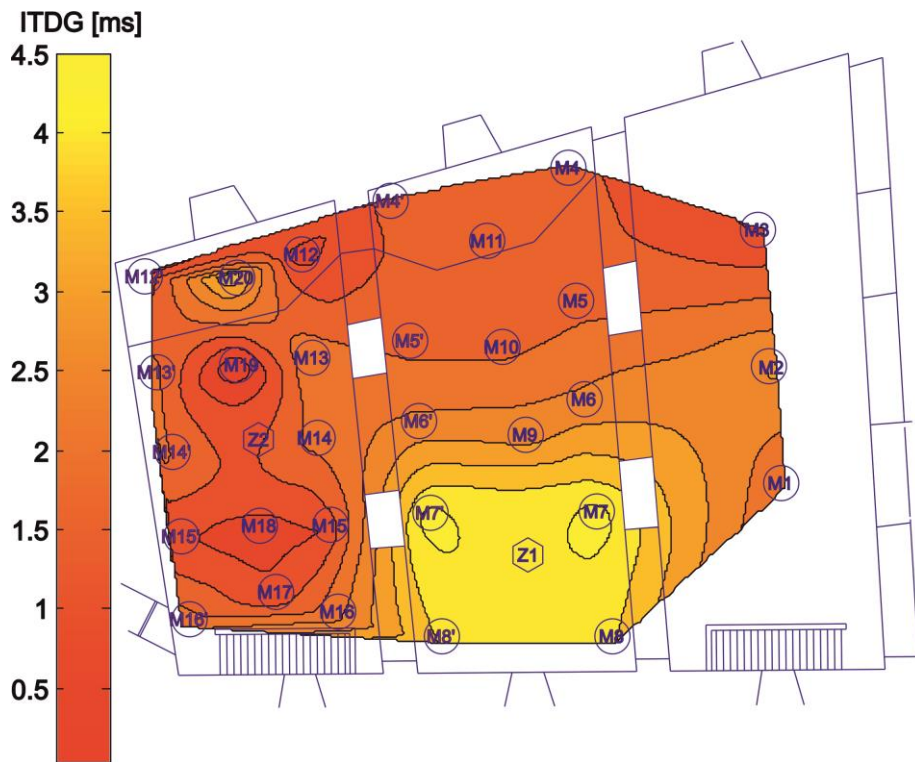
Venues - Revelin Fortress



Venues - Revelin Fortress



Venues - Revelin Fortress



Venues - Revelin Fortress

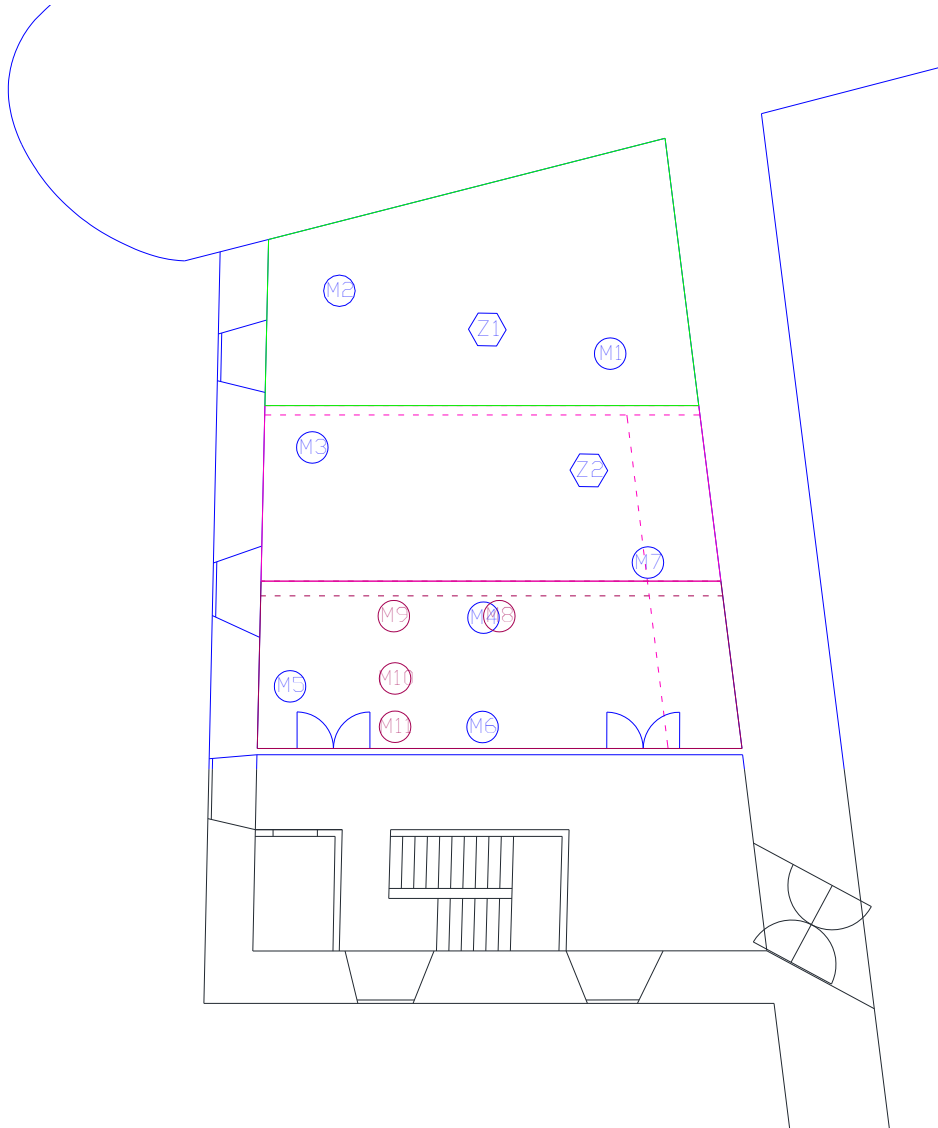
Revelin Fortress	RT_{60} (s)	EDT (s)	BQI	G_{mid} (dB)	C_{80} (dB)	$ITDG$ (ms)	V/N (m ³ /pers.)	STI
Measured values	1.34	1.30	0.63	0.7	1.6	2.56	6.8	0.58
Symphonical music								
Chamber music								
Opera								
Speech								
Cinema								

Venues - Slanica Concert Hall

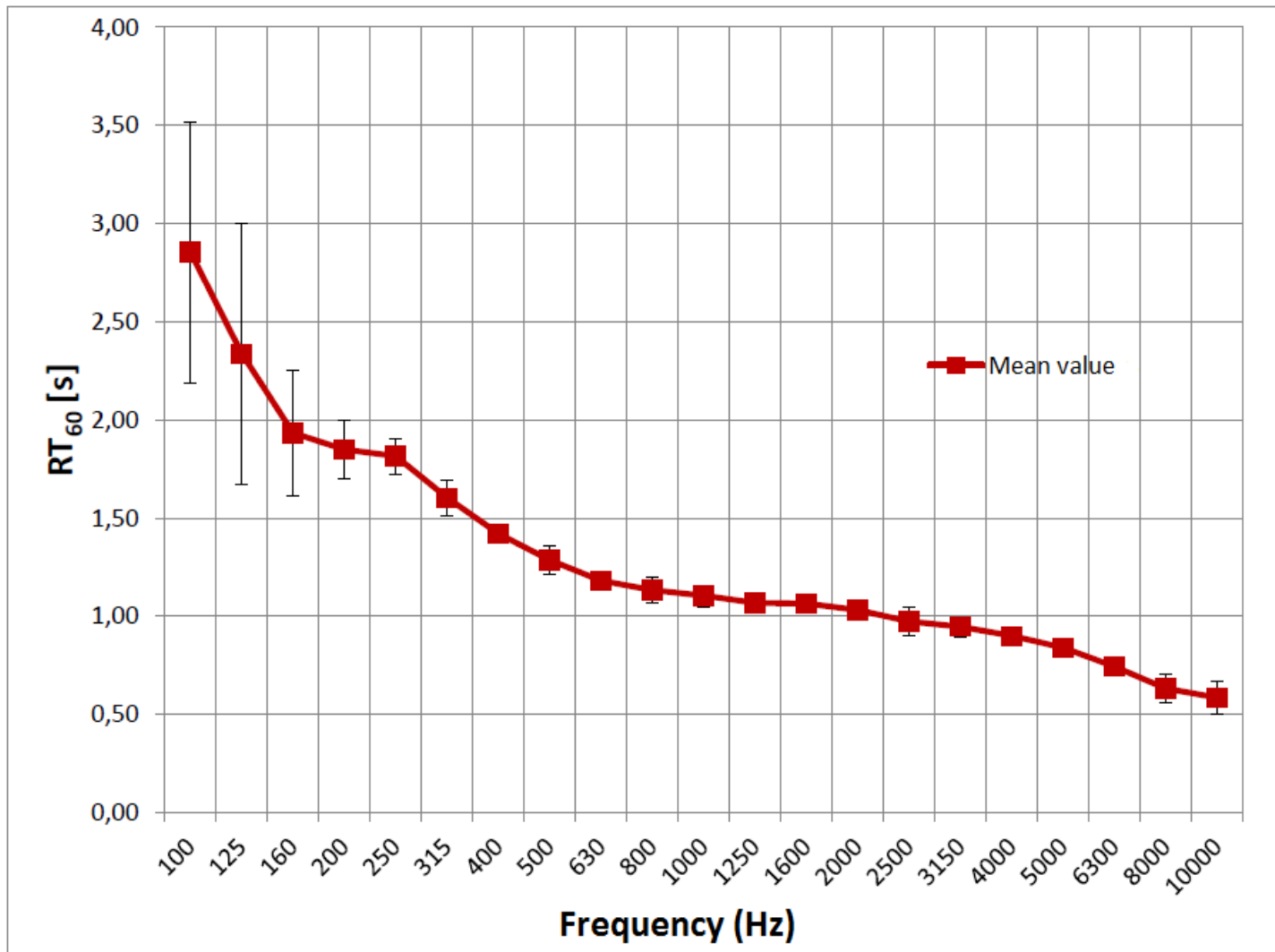
- a part of Revelin Fortress
- rehearsal space for Dubrovnik Symphony Orchestra
- volume = 685m^3
- 170 seats



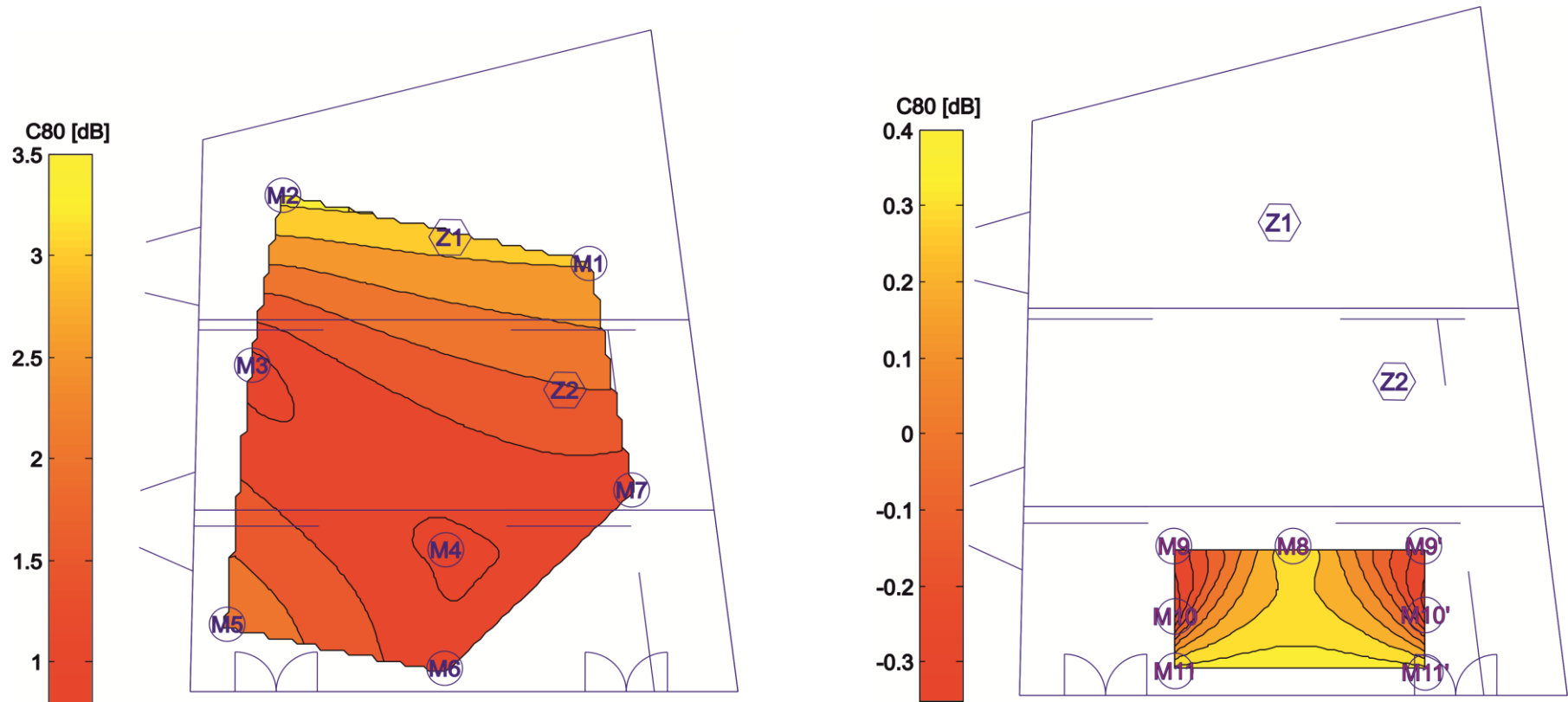
Venues - Slanica Concert Hall



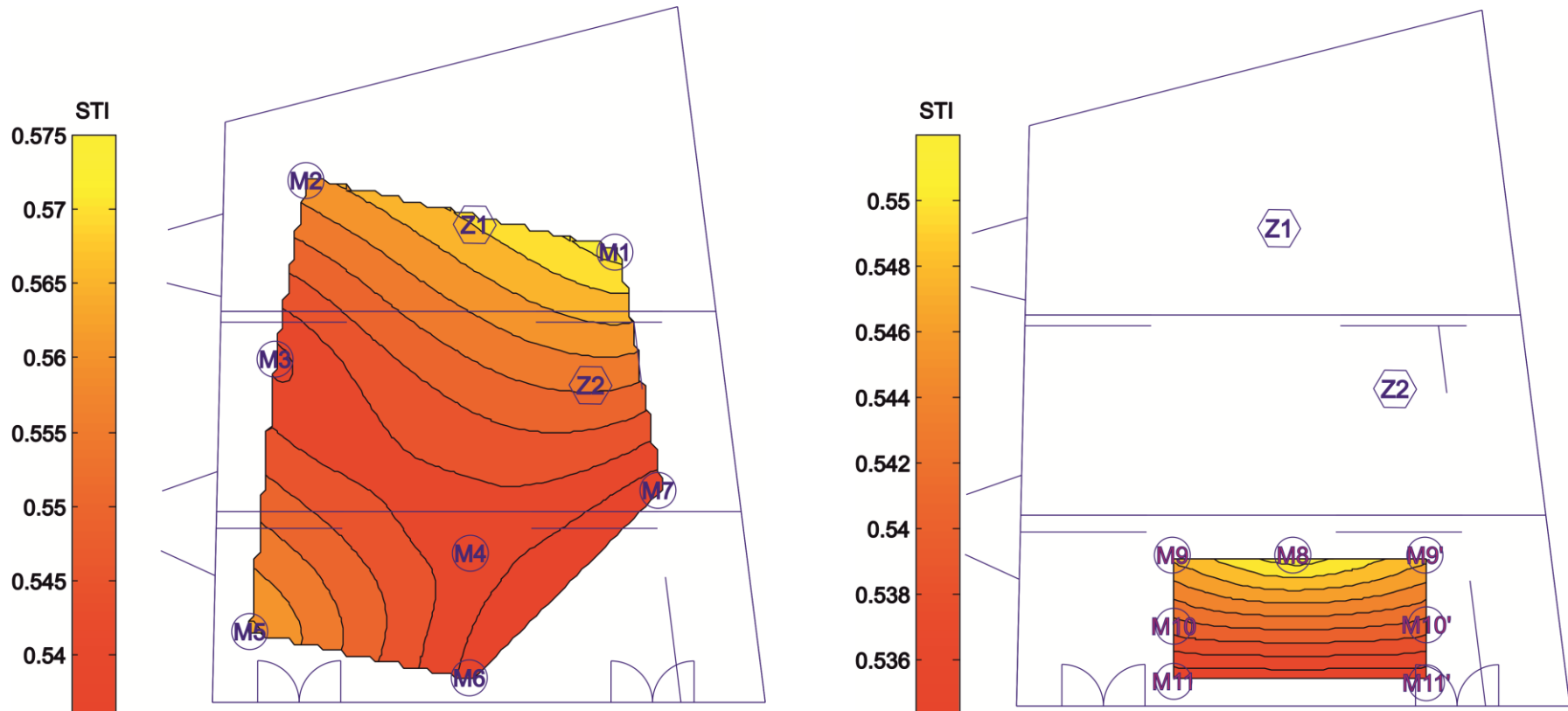
Venues - Slanica Concert Hall



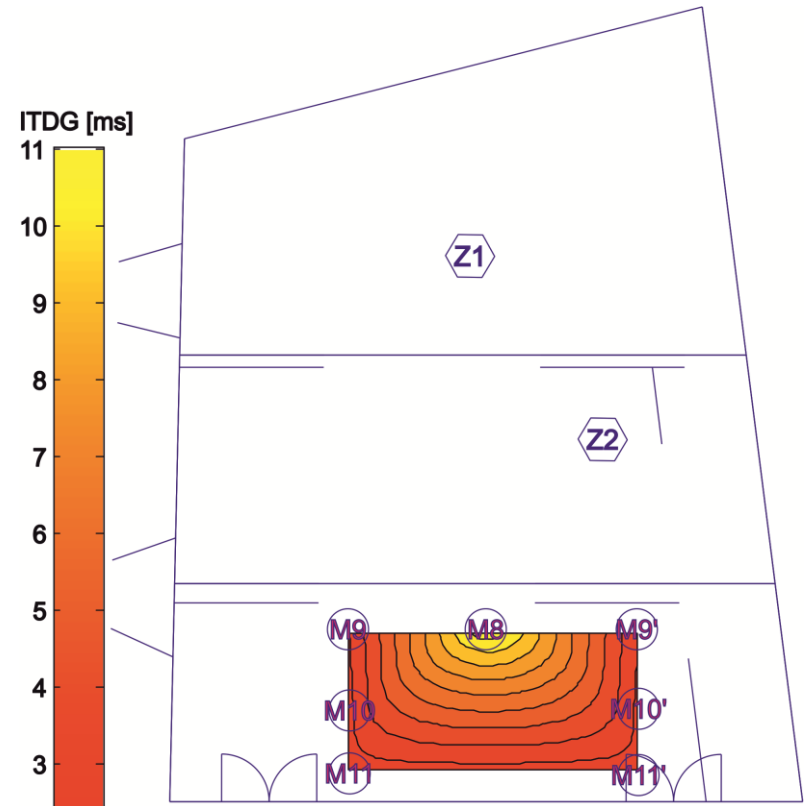
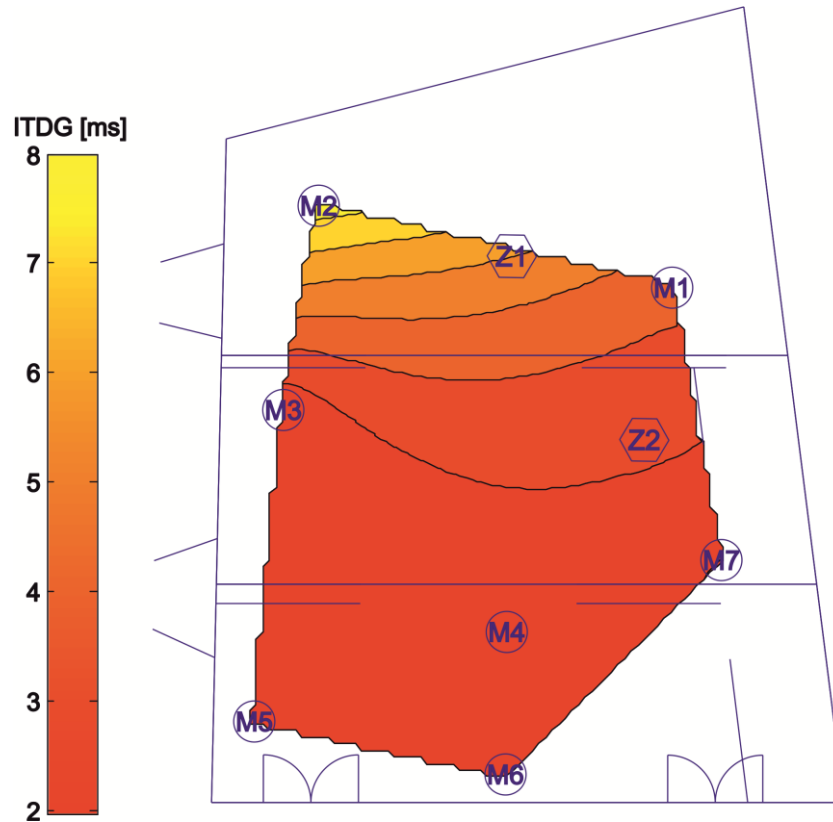
Venues - Slanica Concert Hall



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Venues - Slanica Concert Hall

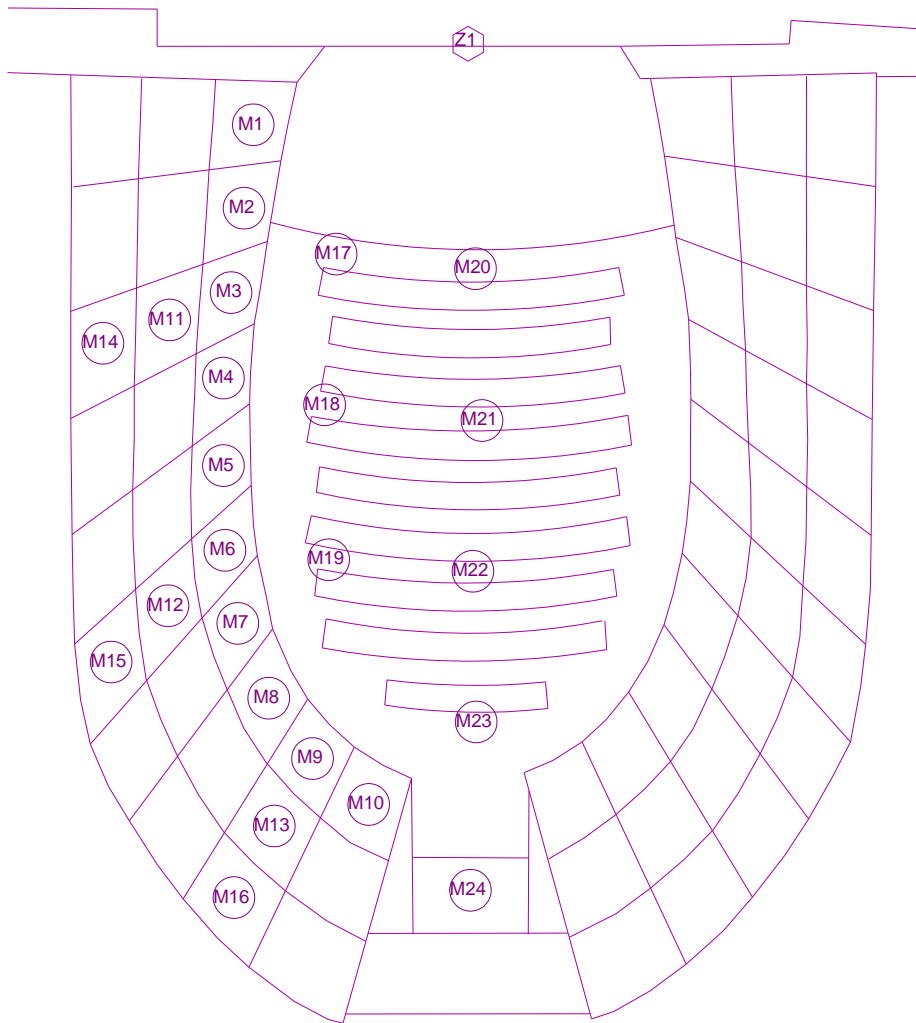
Slanica Concert Hall	RT_{60} (s)	EDT (s)	BQI	G_{mid} (dB)	C_{80} (dB)	$ITDG$ (ms)	V/N (m ³ /pers.)	STI
Measured values	1.20	1.20	0.72	5.7	1.6	3.74	4.0	0.56
Symphonical music								
Chamber music								
Opera								
Speech								
Cinema								

Venues - Marin Držić Theatre

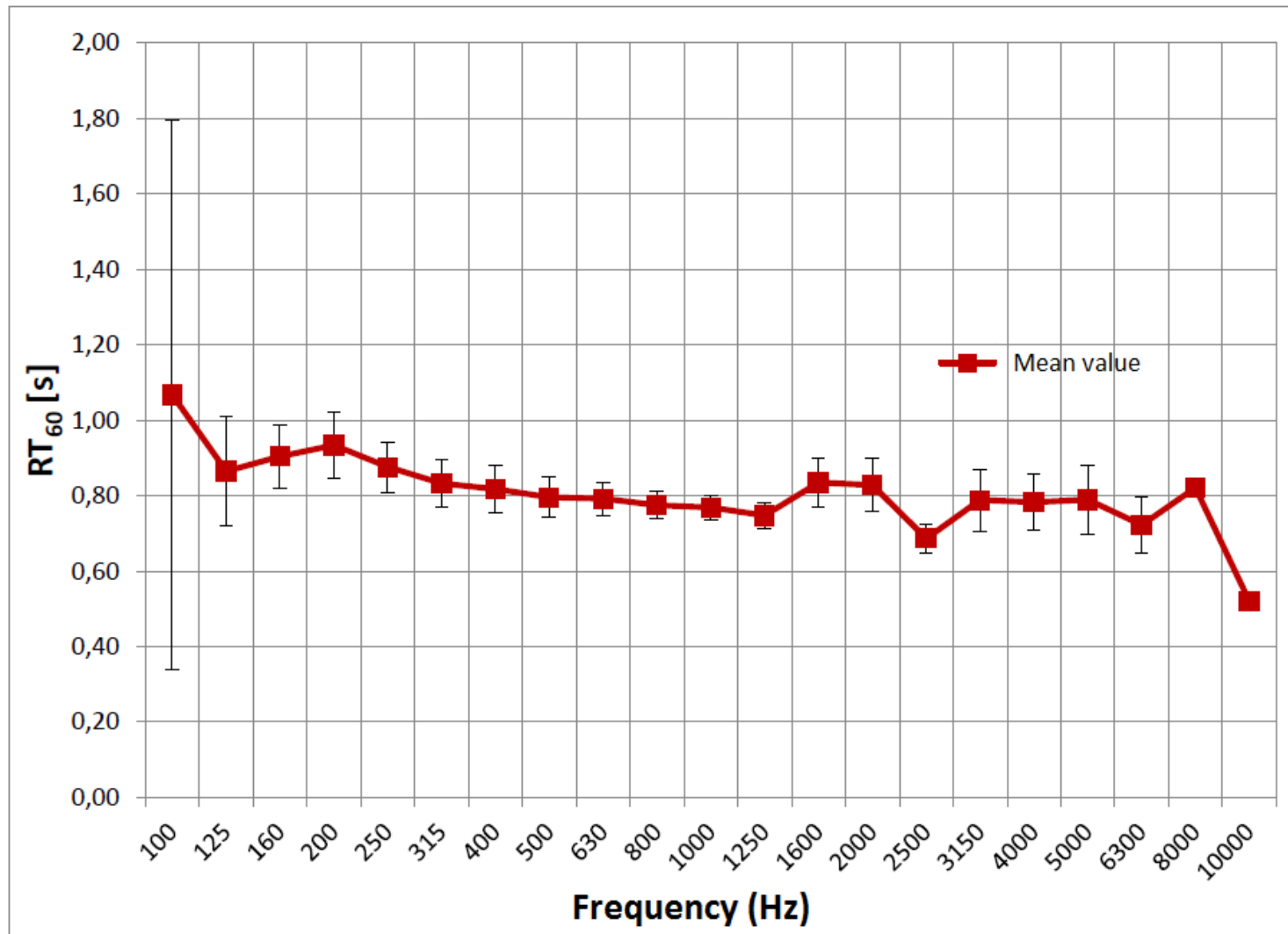
- 19th century
- long tradition of theatre performance
- volume = 1640 m³
- 283 seats



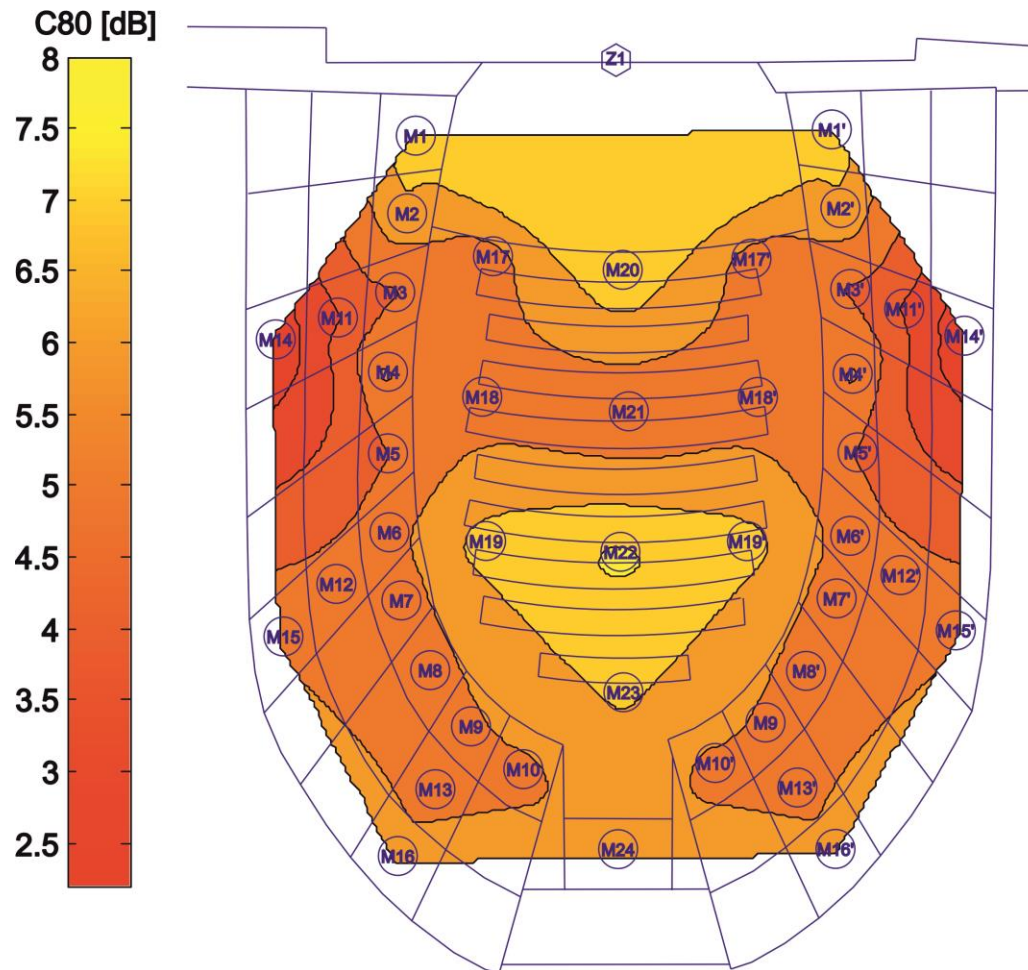
Venues - Marin Držić Theatre



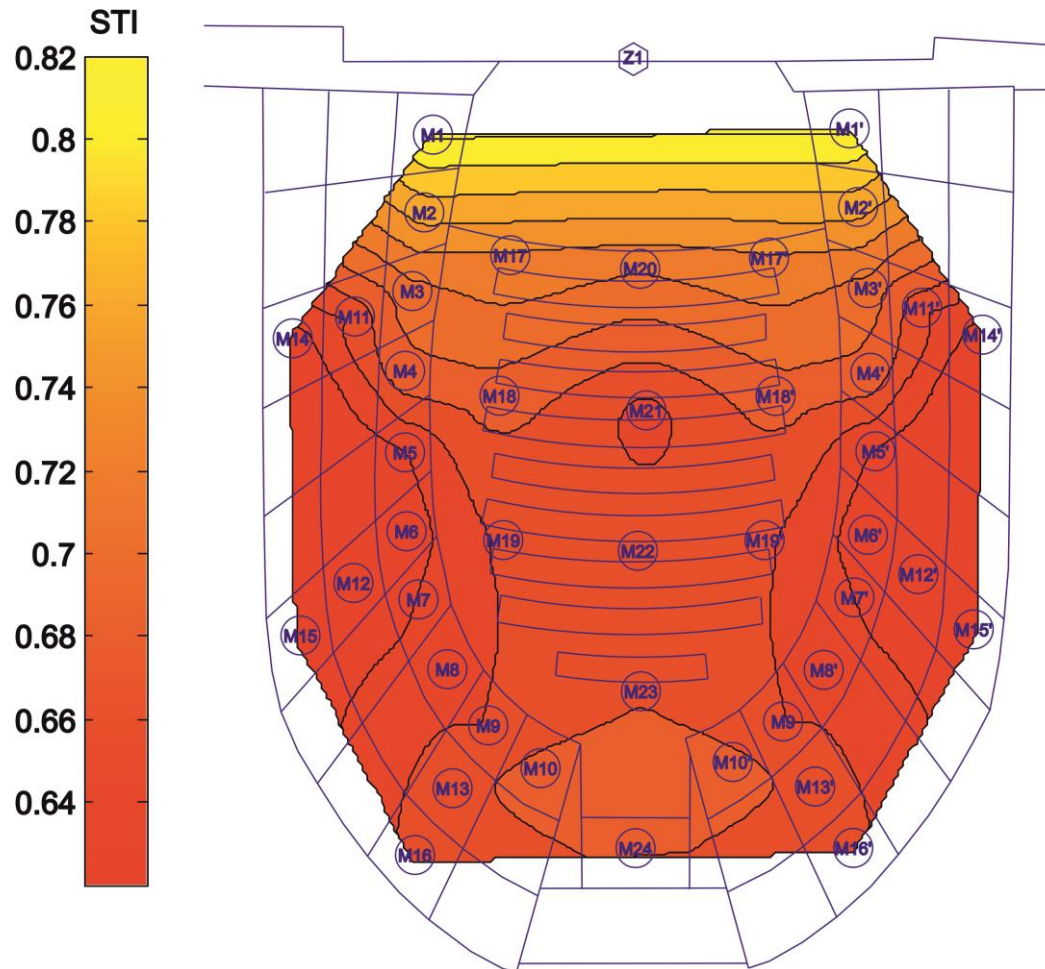
Venues - Marin Držić Theatre



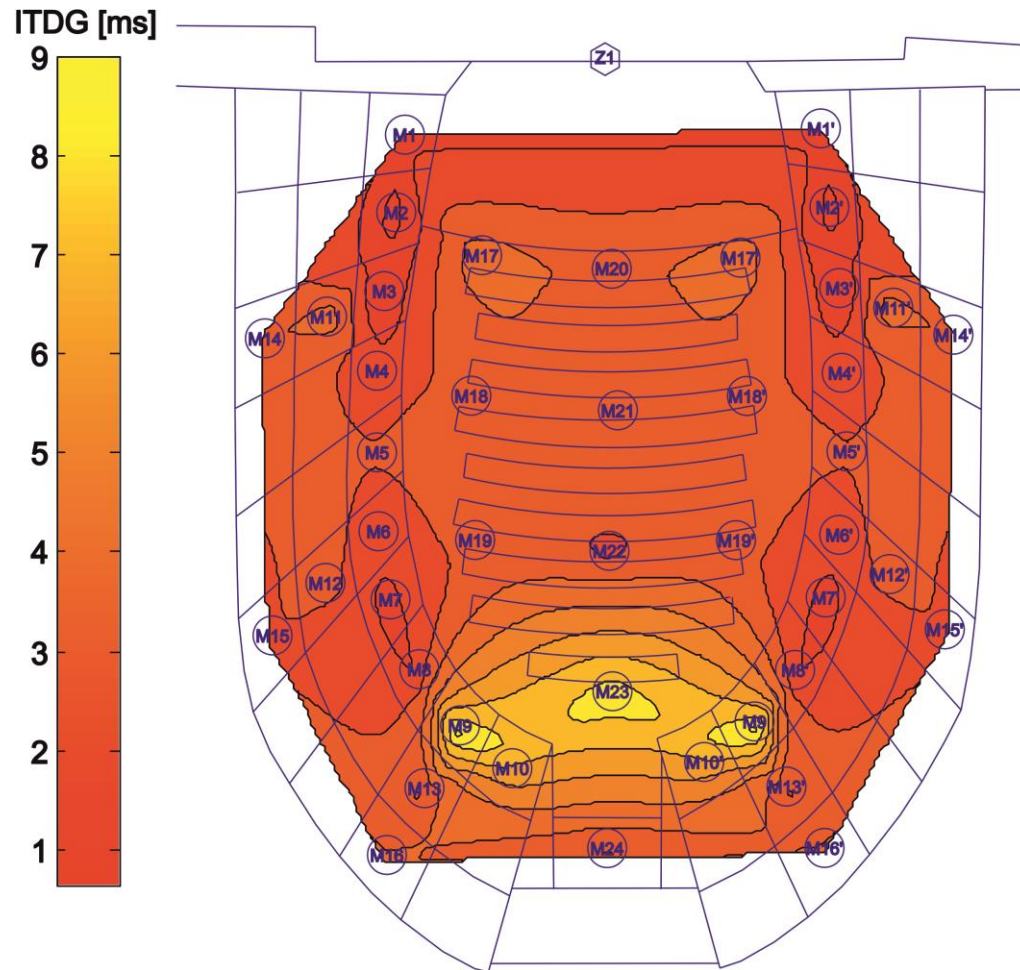
Venues - Marin Držić Theatre



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Venues - Marin Držić Theatre

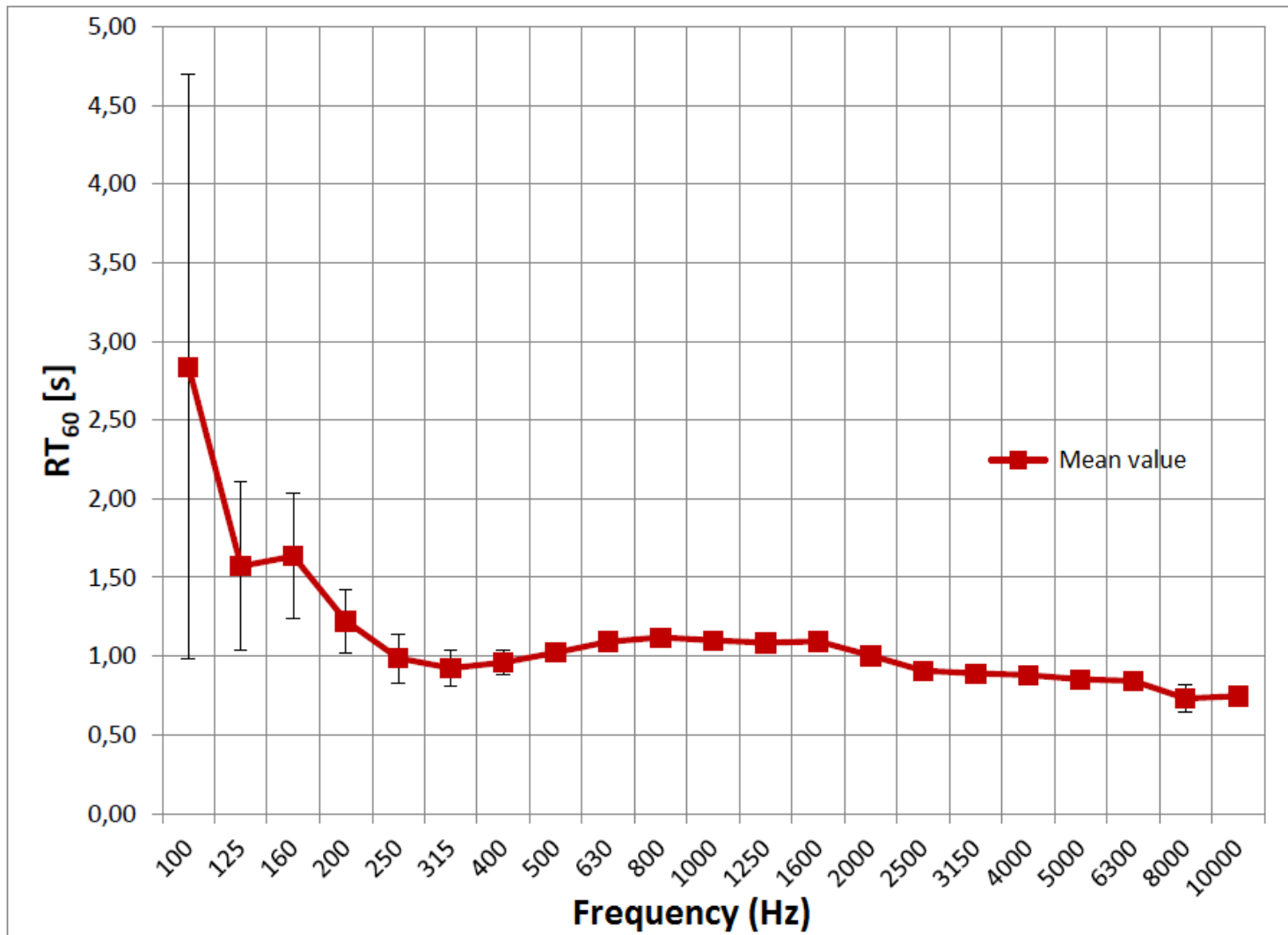
Marin Držić Theatre	RT_{60} (s)	EDT (s)	BQI	G_{mid} (dB)	C_{80} (dB)	$ITDG$ (ms)	V/N (m ³ /pers.)	STI
Measured values	0.78	0.72	0.71	1.6	5.9	4.20	5.8	0.68
Symphonical music								
Chamber music								
Opera								
Speech								
Cinema								

Venues - Sloboda Movie Theatre

- modern
- movie screenings
- volume = 1350 m³
- 160 seats



Venues - Sloboda Movie Theatre



Sloboda Movie Theatre

Sloboda Movie Theatre	RT_{60} (s)	EDT (s)	BQI	G_{mid} (dB)	C_{80} (dB)	$ITDG$ (ms)	V/N (m ³ /pers.)	STI
Measured values	1.06	0.94	0.75	4.6	3.6	4.38	7.7	0.62
Symphonical music								
Chamber music								
Opera								
Speech								
Cinema								

Suitability for primary purpose

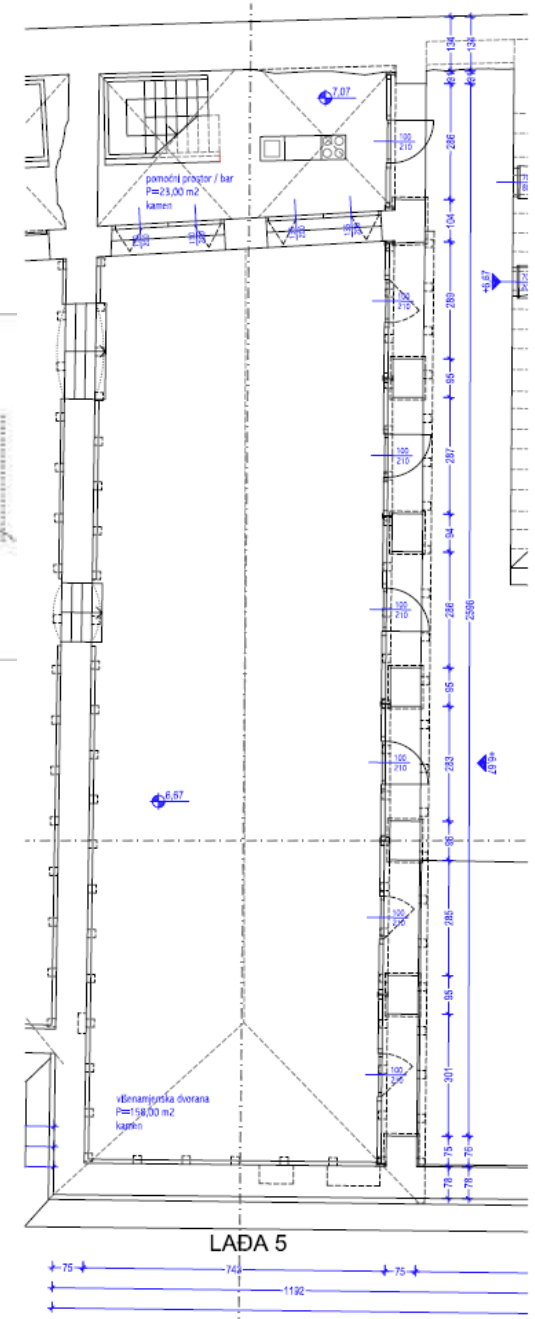
	Rector's Palace	Revelin Fortress	Slanica Concert Hall	Marin Držić Theatre	Sloboda Movie Theatre
RT_{60} (s)	3.80	1.34	1.20	0.78	1.06
EDT (s)	3.72	1.30	1.20	0.72	0.94
C_{50} (dB)	-8.1	-1.3	-1.3	2.1	0.1
C_{80} (dB)	-5.5	1.6	1.6	5.9	3.6
G_{mid} (dB)	7.0	0.7	5.7	1.6	4.6
LF_E	0.20	0.10	0.23	0.12	0.13
BQI	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 /prs.)	9.7	6.8	4.0	5.8	7.7

Venues - Lazareti

- built in 1642
- old Dubrovnik harbour quarantine
- volume = 1000 m³
- 166 seats



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Conclusions

- spaces not built for their present purpose → partly acoustically inappropriate
- certain improvement possible in some spaces (historical appeal)
- evaluation in the unoccupied state → improvement with people present
- evaluation of suitability using a novel table with colour-coded suitability marks (red for unsuitable, yellow for borderline suitable and green for suitable)

Thank you for your attention!