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RECENT EXPERIENCES IN ACOUSTIC DESIGN OF MUSICAL INSTITUATIONS IN HUNGARY

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ABSTRACT

Musical institutions are often built around the basic needs of artists and therefore acoustic qualities of stages and rehearsal spaces are of main concern.
The paper summarizes experiences of the author in the planning, designing and commissioning procedures of musical institutions of the last decade in Hungary. These institutions include facilities of both classical, folk and modern music. Aspects of regulations, standards, architectural concepts, client involvement, methods are discussed. Main measurement results of room acoustics and sound isolation are presented.
Upon these experiences the author suggests a set of acoustic requirements, and to follow certain procedures during planning and commissioning in order to keep the role of acoustic designer in the right spot.

Keywords: *room acoustics, musical facilities, design procedure, project management.*

1. INTRODUCTION

Buildings of musical institutions are one of the few types of facilities where the importance of acoustic design was in question before any acoustic standard came into being.
However, despite decades past since the first room acoustics standards were published and the considerable amount of research available, there is no broadly accepted practice for acoustic design. In the experience of the author, there are as many practices and attitudes as there are design offices.
The aim of the author is to achieve a verifiable, reproducible, objectively justified procedure. It is also an obvious aim to identify design approaches with the least uncertainties and evaluation methods, that can safely identify the causes of any dissatisfaction. Not surprisingly, communicating acoustic quality, problems and potentials is also a major challenge, not only to users but also to investors, contractors and co-designers.
Each of these topics is a research area and conference theme in its own right, so this paper presents only some of the most interesting lessons learned and outline a possible way forward.
The cases presented are selected examples from the works of the author of Hungarian music institutions over the last 15 years.

2. BACKGROUND

2.1 Regulations on Acoustic Planning in Hungary

Hungarian building regulations only recognize noise and vibration protection as essential building characteristics among the acoustic characteristics. Not room acoustics.
There is a decree on noise and vibration levels (see [1]) and a standard for sound insulation (see [2]). These mention categories like lecture rooms, music classrooms or concert hall, but not in a consistent way and hardly mentioning functions, like musical performance or rehearsal spaces.
A national standard for room acoustic quality has been in published recently (see [3]). It includes room acoustics requirements for speech, amplified and acoustic music performance rooms. Requirements set a mean reverberation time (averaged over 250 Hz…2 kHz octave bands) as a function of volume and a frequency-dependent tolerance for reverberation time. No other requirements are specified, but informal appendices include some useful information to help checking visibility along sloped audience areas and room dimensions for speech classrooms.

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Involvement of an acoustician is not required in general. Only declaration of environmental noise emission control is required explicitly. Otherwise it is sufficient for the responsible designer to declare compliance with other acoustic requirements.
Fortunately, the absence of an acoustic designer or expert is becoming increasingly rare. Regulation of competences in acoustic fields is not clearly settled yet.
Basically, there is no requirement on the design content, so content, scope and quality of acoustic documentations vary rather much. The author did write recommendations for the engineering chamber in Hungary, but it is not consensual.

2.2 Design Process

Typical design stages and roles are shown in Fig. 1 as experienced by the author. Not all stages appear in projects, but permit and construction stages are clearly defined. Bidding for construction works is sometimes based on permit level documents with loose specifications, which makes continuous quality assurance difficult.
Design and engineering teams are led and coordinated by architects exclusively.
A major combination of problems is, however, that acoustically competent representatives are rarely found on behalf of the client and often there are no resources to support engineering control during construction and evaluation after constructions. This means, that communication and understanding of acoustic requirements is often far from fluent and the overall tolerance against acoustic problems is rather high. This also means, that real acoustic problems are rarely spotted, evaluated and corrected even in the case of musical institutions.
In the praxis of the author, acoustic measurements after or during constructions are often carried out and organized by the acoustician for own interest with no mandate, only to collect data and experience, sometimes years after completion.

2.3 Specification of Acoustics in the past decades

For music rehearsal or recital rooms in Hungary there are no specific regulations, so the usual practice was to specify

- background noise levels 5…15 dB below 40 dB $L_{Aeq,T}$ required for regular classrooms or lecture halls,
- vibration levels required for cultural buildings,
- minimum airborne sound isolation using R_w+C measure and maximum impact noise level in L'_{nw} measure required for classrooms or lecture rooms, corrected by 5…15 dB and using C_{tr} instead of C where possible.

Since room acoustics as such had been completely missing from national standards, the usual specification included:

- mean reverberation time T_m maximum (general) or acceptable range (musical applications)
- frequency dependent tolerance of spatially averaged reverberation time (see Fig. 2) is given by shape parameters *a* (ripple), *b* (bass) and *c* (high end roll-off)
- clarity measures (C_{50}, C_{80} or equivalent) in acoustically critical spaces (e.g. performance or lecture spaces)
- speech transmission index (STI) only where a PA system is used
- spatial variance of parameters for rooms with large floor area and larger number of occupants or audience.

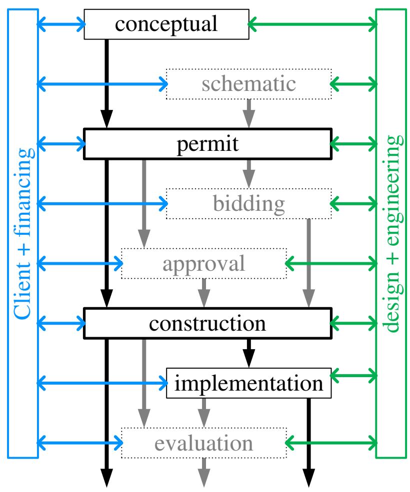

Figure 1. Scheme of typical design stages and roles. Timeline is from top to bottom.

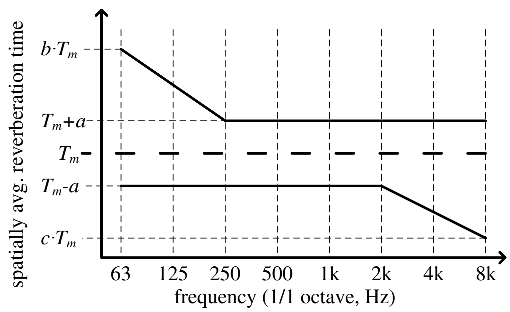

Figure 2. Scheme of typical design stages and roles. Timeline is from top to bottom.

Other room acoustic parameters like early decay time (EDT_{10}), strength (G) and spatial measures (LF or IACC) were mentioned or considered only for performance spaces.
Requirements are applied to furnished, uninhabited and unoccupied rooms, HVAC systems set to operational levels,

assuming normal activity noise levels in adjacent spaces and normal traffic conditions in the environment.
Other standards or recommendations have been applied upon requirements of the client or internationally acclaimed certifications (BREEAM, LEED, WELL etc.).

3. EXPERIENCE WITH RECENT PROJECTS

Table 1 summarizes description of selected projects of the author in the past 15 years, involving musical institutions. The table denotes affiliation of the author by D (design or engineering) and C (control, commissioning).
The range includes renowned public institutions (LW, LF, SO, ND), private institutions (HA, GR, BM), institutions of smaller organizations or communities (PE, SA, CS). Most institutions are for both performance and rehearsal (LF, SO, HA, BM, PE, ND, SA, CS), others are only for rehearsal (LW, GR). Except SA, all projects were based on existing buildings with all their constraints. Project ND and partially LW, HA, BM included brand new building structures as well. Projects LF and SO are about restoration of highly protected historical buildings.
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Projects not considered here included other musical institutions too, but involvement of the author was sparse in the timeline of those projects.

Notable aspects regarding the process of each project:

- only projects LW and LF were supported by acoustically competent representative on behalf of the client in decision-making role
- projects SO, HA, BM, PE, CS were supported by representatives of musical background with limited influence
- only projects LW, LF, GR, BM, PE required any control measurements during or after construction works
- only project CS required evaluation of acoustic qualities after moving in
- only project LW and LF involved the acoustic engineer a fully comprehensive way including control measurements
- acoustically relevant complaints were occurred and got resolved in LF, HA, GR, BM (described later)
- acoustically relevant complaints were identified but got no resolution in CS and PE,
- room acoustic modelling was necessary only in performance spaces.

To provide an overview, mean reverberation time measurement results are shown in Fig. 3.

3.1 LW and LF projects

The long-term project included the restoration of the historical building (LF), renovating a former residential building into a modern music education building (LW) and some minor temporary facilities to ensure operation of the institution during constructions works.

Table 1. Selected projects of musical institutions.

ID	aim	environmental acoustics	MEP acoustics	sound isolation	room acoustics	audio systems	description
LW	complete renovation	D + C	D + C	D + C	D + C	D + C	existing residential building, new educational building, many rehearsal rooms + frontal classrooms + studios
LF	historic building restoration	D + C	D + C	D + C	C	D + C	existing and historical educational and event functions renovated, many instrumental classrooms + concert halls + studios
SO	orchestra shell	-	-	-	D	-	existing situation, study conditions of orchestra performing on main stage
	historic building restoration	C	C	C	C	D	existing and historical event functions, opera hall/stage/pit + rehearsal rooms + studios
OT	orchestra pit & sound system	-	-	-	D + C	D + C	historic building, used for musical, investigation of balance of stage, pit and PA system for possible improvements
ND	complete renovation	D + C	D + C	D + C	D + C	-	previously TV studio from industrial building, renovation to dance theatre with additional spaces, event halls + rehearsal rooms + studios
HA	complete renovation	D + C	D + C	D + C	D + C	D	existing cinema building, new event center function, concert/event hall + rehearsal rooms + club
BM	complete renovation	D + C	D + C	D + C	D + C	-	existing residential building, complete reconstruction, multifunction event hall + club + rehearsal rooms + studios
GR	new (basement)	D + C	D + C	D + C	D + C	-	existing residential building, new rehearsal rooms of amplified music, focus on sound isolation
SA	new building	D + C	D + C	D + C	D + C	-	completely new building in a court, event hall + rehearsal rooms + studio
PE	correction	-	-	D + C	D + C	-	existing old building with event hall and studio, acoustic corrections

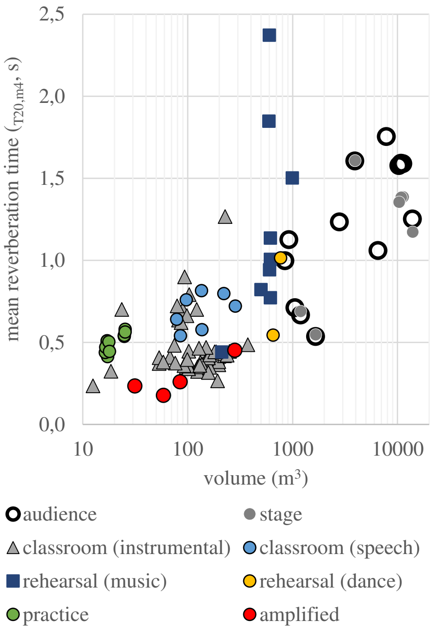

Figure 3. Mean measured reverberation times for each of the 113 rooms.

The project leader on behalf of the client was acoustically competent, which was necessary to control the full process from the engineering part.

Major concerns were:

- keep and possibly improve acoustic characteristics of historic performance spaces, considering, that even a slight change in the color of finishes could cause 'acoustic' concerns in frequent visitors
- improve sound isolation between rooms
- accommodate modern MEP (mechanic, electric, plumbing) systems with no acoustic side effects.

Possibilities of sound and vibration isolation solutions were further narrowed by the limited load bearing capacities of existing building structures.

Acoustically interesting details:

- airborne sound isolation $R'_w+C_{tr}>65$ dB (see Fig. 5) and impact noise levels $L'_{nw}<35$ dB could be achieved between adjacent classrooms and rehearsal rooms using lightweight constructions in the historic building;
- timber supporting structure of hollow floors of concert halls could be renovated with improved vibration properties; engineering included vibration measurements and modelling
- renovated rehearsal and instrumental classrooms in the historic building were found to be too dry after moving in, possibly due to comparison to previously untreated conditions
- sound isolating restoration of historic doors of concert halls proved to be too hard to operate properly (weight);
- properly installed indoor units of HVAC systems together with traffic noise caused noise levels below 30 dB L_{Aeq} and NC25 or NR25.

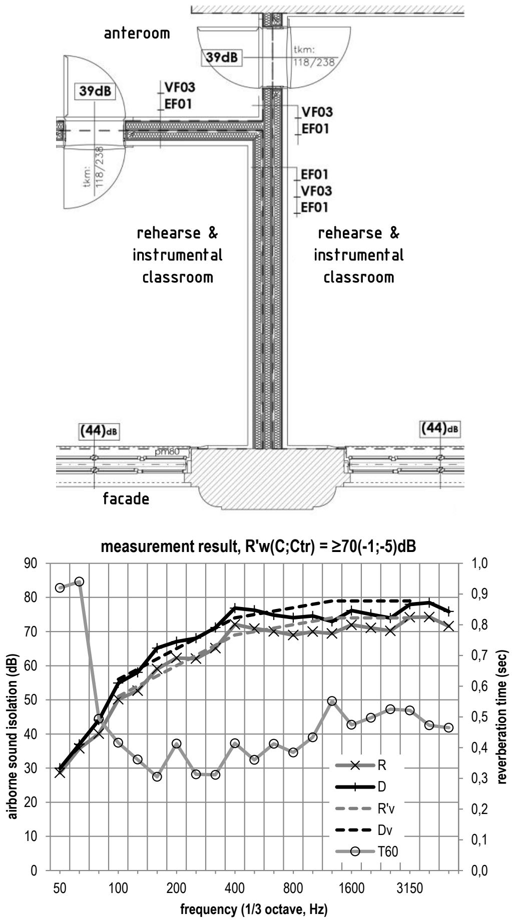

Figure 4. In situ sound isolation measurement between two classrooms in project LF, after construction (top: floor plan from acoustic document, bottom: results and evaluation).

Fig. 4 shows reverberation times of identical small individual practice rooms in the new building measured using switched noise and evaluated using handheld instrument. Variability at even low frequencies was impressively low.

Overall, restoration and renovation of both buildings proved to be successful and a good example of effective engineering control. Post construction evaluation is lacking, however.

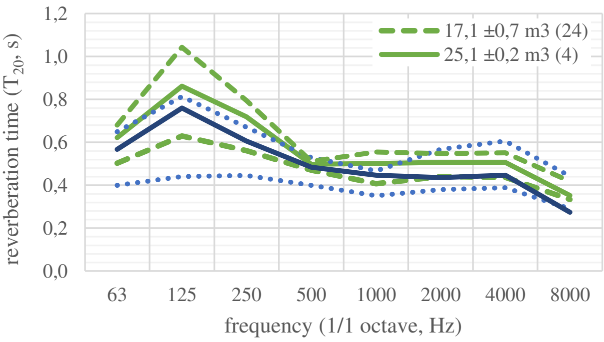

Figure 5. Reverberation times of nearly identical small individual practice rooms.

3.2 SO project

Before recent complete restoration of the historical building, there had been attempts to improve acoustics of the main hall for orchestral performing on the stage, due to complaints when using a lightweight (more visual than reflective) orchestra shell in the otherwise empty stage.

Measurement results confirmed, that existing orchestra shell solution is not effective at all, there is hardly any effect of shell size and position on the audience area (see Fig. 6) and the empty stage late reverb is not isolated by the shell either.

Renovation eventually involved the entire building, including rehearsal rooms, but in this project the author was involved only to design audio systems and to control acoustic design, however the author is not aware if any acoustic control measurements were carried out during or post construction.

3.1 OT project

After a complete restoration of the historical building, there have been several attempts to improve acoustic issues in the audience area, related to the unbalance between sound from the pit, stage and PA system. The repertoire consists mainly of modern musicals and a PA system must be used.

Figure 7 shows a longitudinal section of the hall with stage, pit and measurement points in audience area with representative results (250 Hz-2 kHz mean values of C_{50}, C_{80} of ISO 3382-1, early/direct ratio $M_x = 10 \cdot lg(E^x_{5ms}/E^{5ms}_0)$ and SPL).

Results confirm, that distribution of sound from the pit is uneven, compared to frontal loudspeaker system. Modelling explained this by the ceiling geometry above pit and that there are no reflecting walls at sides of the proscenium.

It is not possible to modify anything else but the pit. For more control on the sound and considering modern musical performances, the author advised attenuating the pit and screening the pit from the audience area to decrease diffracted sound paths. For more traditional pieces, opening the pit would be necessary.

The large number of open wireless microphones on stage should be decreased and in-ear monitoring should be used to improve separation of performers on stage.

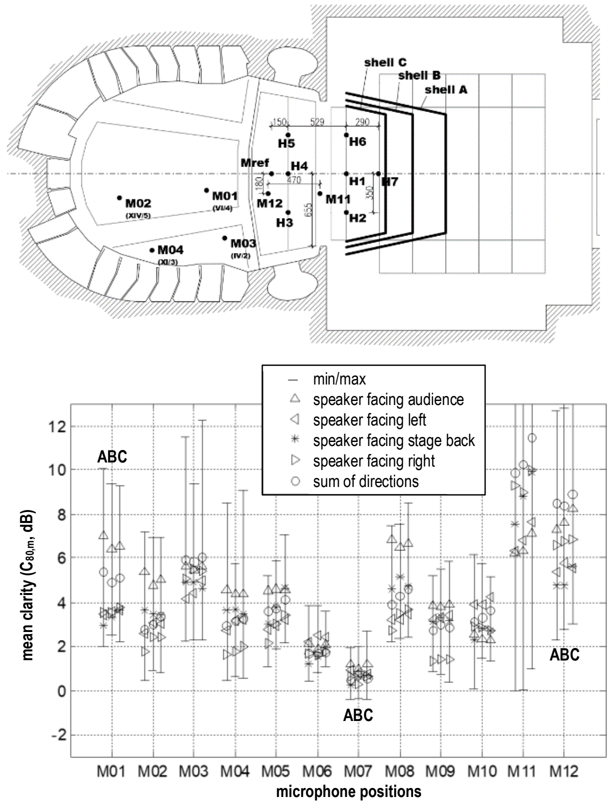

Figure 6. Study of existing orchestra shell acoustic qualities in project SO before renovation (top: stage level floor plan with measurement positions, bottom: analysis of clarity vs. receiver positions) using a directional loudspeaker.

3.2 ND project

The facility was built around a former TV studio, used as multi-purpose event hall and was originally an industrial facility. The renovation included reusing modular acoustic panels of the TV studio, new rehearsal rooms for dancing, and a new chamber hall 'floating' in the new large lobby. The client emphasized importance of folk music and dance performances in addition to the multifunctional uses of performance spaces.

The large hall (see Fig. 8) features a single 13900 m^3 volume for the stage and the audience, a retractable seating on plane flooring and lots of curtains for visual separation and to change reverberation in front of existing acoustic panels. Perforated panels and a ceiling slit resonator were used to balance excess high frequency absorption.

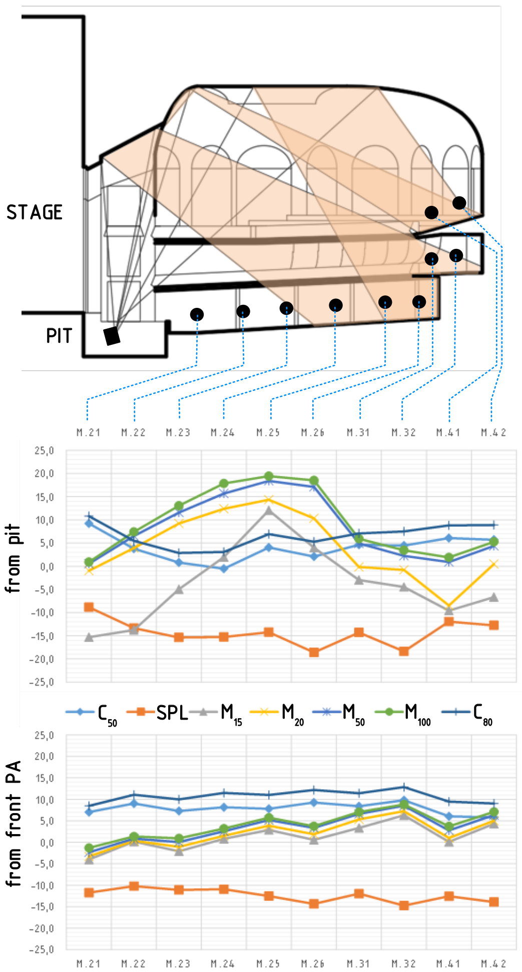

Figure 7. Representative room acoustic parameters measured along the hall, showing that response from the pit is highly uneven, compared to the amplified sound. (note: SPL is offset for better, all in dB).

Measured and expected reverberation times are different in balance mainly, but it is hard to identify causes, because there was no engineering inspection required during construction. There are no complaints, though, except that there is no shell for the rare occasion an orchestra would perform.

The chamber hall accommodates intimate performances mainly of folk music & dance. In order to enhance immersion, seats are fixed to a lightweight floating hollow substructure, which is connected to the stage to transfer haptic feel of stomping of dancers to seats. Engineering inspection (measurement of vibration levels, impact sound isolation, sound levels within room etc.) was required only to select the right stage flooring optimized for dancers.

Dance rehearsal rooms are dominated by mirrors on walls all-around, hence even if the ceiling has sound absorbers, obvious flutter echoes are present.

Sound isolation was measured for the most critical adjacencies only with an emphasis on checking floating floor constructions.

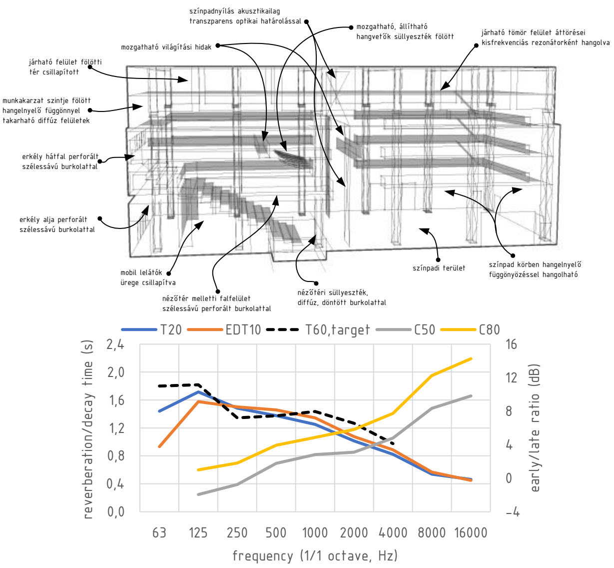

Figure 8. A figure from the acoustic document explaining ND large hall room acoustic details. Measurement results in audience area, theatre setting (empty stage, curtains deployed).

3.3 HA project

A former cinema was rebuilt into a multifunctional musical institute as a private initiative. The building includes a 4000 m^3 multifunctional hall, a small chamber hall, orchestral and dance rehearse halls and a club in the basement.

The client's representative has a non-professional musical background with the right balance of engineering, artistic and managing attitude. The budget was kept to a minimum, but finally all the goals were achieved. Only occasional site inspections were required with no control measurements.

A correction in the choir rehearse room was necessary due to deviations from the design and the wish for a more diffuse sound.

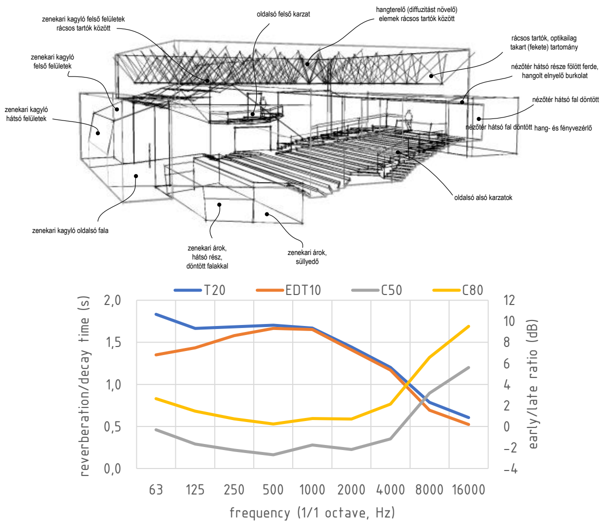

Figure 9. A figure from the acoustic document explaining HA main hall room acoustic details and measurement results in concert hall setting.

3.4 BM project

A former residential building was rebuilt into a multifunctional musical institute as a private initiative. The building includes a 2800 m^3 multifunctional hall (former court of the building), a studio, several small rehearse rooms and a jazz-club in the basement.
The client was a musician with a strong background as a musical manager. The budget was kept to a reasonable minimum and all the goals were achieved or exceeded. A series of post-construction sound isolation control measurements and a loose but regular site inspection were required.

3.5 GR project

A private investor built multiple rehearse rooms in the basement of an old residential building for rock and jazz bands. The main concern was sound isolation to flats directly above on the ground floor. The box-in-box concrete construction could achieve the required isolation, but multiple corrections of construction errors were necessary based on vibration level measurements upon complaints.

3.6 SA project

A small city built a 930 m^3 chamber hall for the community and the local music school. The building has also smaller rehearse and lecture rooms and an exhibition space in the lobby.
Model of the geometry of the chamber hall is shown in Fig. 11 with measurement results. Only occasional site inspection and no control measurements were required by the client.

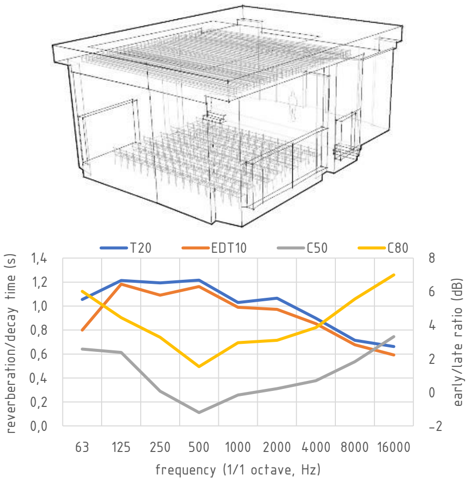

Figure 10. A figure from the acoustic document of SA concert hall and measurement results in concert hall setting.

4. DISCUSSION

Most of the projects of musical institutions in recent 15 years of the praxis of the author were renovations or restorations of existing institutions. A smaller group of projects were new institutions with buildings rebuilt from existing buildings.
Besides geometrical and structural constraints of existing buildings, acoustic properties of existing structures rarely could be checked.
After publishing design documents, acoustic engineering control of the bidding process and construction works, regular site inspection or control measurements were just occasionally required. In most cases, the author asked for the opportunity to make measurements and to collect experience from the users for his own interest.
All project were reported as successful in publications, even if there was no engineering evidence at the time of opening.
It had never occurred, that an institute was willing to publish any acoustic measurement results, even if measured results were fine and the project was funded from public money.
In the view of the author, this practice is far from ideal. With no engineering control and no feedback of objective (measured) data, acoustic engineering achievements or failures cannot be studied.

4.1 Practice and realities vs. regulations and standards

Currently there is no unified, consensual, national or international regulation or recommendation in building acoustics, that includes issues of noise levels, sound isolation, room acoustics and documentation requirements.

The ISO 23591:2021 [4] standard is an important effort, but a retrospective check of rooms of earlier projects resulted, that none of the rooms complies recommendations of this standard, mainly due to mean reverberation time, reverberation time tolerance or low volume.
Yet there are hardly any problems reported from those projects from clients or users. This could mean, that either recommendations are too tight or that users are not aware enough to notice if there is an acoustic issue.
Actually, if ambience fits, surprisingly odd locations (e.g. the lobby of ND or the library of BM are popular) can accommodate exceptionally successful performances.
Before creating any new standards, regulations or even recommendations, minimum set of physical parameters and content of design documentation should be agreed.

4.2 Suggestions

In case of rooms where music or audio communication is of importance, the author would encourage acoustic practice as follows:

- responsible persons must be designated with whom one can communicate real needs and expectations
- awareness of clients & investors: acoustic qualities are in jeopardy if engineering control is sparse or lacking,
- comprehensive measurements and evaluation: it should be self-evident to make objective assessments
- awareness of users: educate musicians to recognize, to collect and to communicate experiences
- publish/share measurement results: shared data should be analyzed to make consensual conclusions.

Regulations, standards and recommendations need to be revised to support the aims above and to provide guidance and enhance applicability in real world situations.
Sets, definitions and uses of basic quality descriptors need to be revised, too. New types of parameters are needed, while a hierarchy (an example, see Fig. 11) could be agreed upon not to miss causation and to focus on the bottom line.
Uncertainties in calculation methods and material descriptors should be communicated clearly both in specifications and predictions (e.g. data or results below 100 Hz, above 4 kHz).
Finally, clients would certainly appreciate more intuitive descriptors and practical measures of just meaningful differences (JMD, similar to [6]) than current metrics.

5. SUMMARY

Regulations and standards in Hungary did not support acoustic design decisions and importance of responsible acoustic engineers in projects about performing or rehearsal spaces until recent years. Projects of the author involved were completed with satisfaction, even if design targets were not exactly met and a retrospective analysis against ISO 23591 standard showed no compliance. Design targets were met in cases, where the client was willing to require continuous acoustic engineering assistance.
Suggested practice requires change of attitude in many ways of all parties and a lot of work in the professional community to achieve a consensual view on basic acoustic qualities.

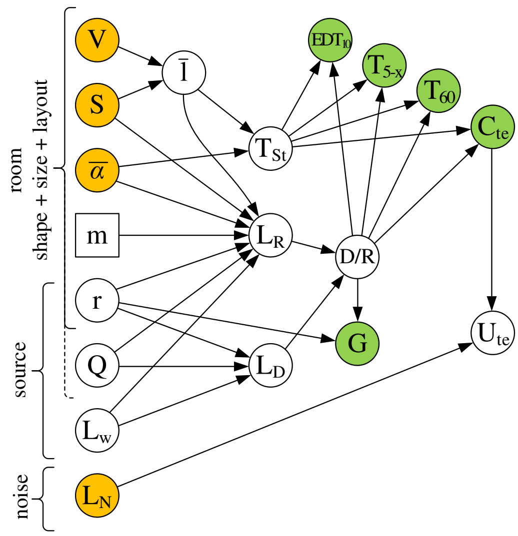

Figure 11. Tree of causation of the most basic acoustic parameters derived from equations in [5]. Arrows point from causes to effects. Orange: attributes that can be controlled. Green: standard room acoustic parameters.

6. REFERENCES

[1] 27/2008. KvVM-EüM decree on environmental noise and vibration load limit values

[2] MSZ 15601-1:2007 Building acoustics. Part 1: Sound insulation requirements inside building

[3] MSZ 2080:2020, "Acoustics. Specifications and recommendations for room acoustic design"

[4] ISO 23591:2021, "Acoustic quality criteria for music rehearsal rooms and spaces"

[5] A. T. Fürjes: "Comparing Derivation from the Revised Theory of Sound Level Distribution in Rooms to Measurement Results", *DAGA 2023* preprint pp. 1307-1310

[6] W. M. Whitmer, D. McShefferty, M. A. Akeroyd, "On Detectable and Meaningful Speech Intelligibility Benefits" *Adv. Exp. Med. Biol.* 2016; 894:447-455