ACOUSTICS OF VANISHED 19th CENTURY CONCERT HALLS IN HELSINKI

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1 INTRODUCTION

Helsinki became the capital of the Grand Duchy of Finland in 1812, three years after the war between Sweden and Russia. After the former capital Turku burnt disastrously in 1827, the University moved to Helsinki. After that, Helsinki soon developed into the Finnish center of music. In the end of the 19th century, there were three theatres and at least four large halls suitable for the performance of orchestral music.

The most important venues for the performance of orchestral music were the first and second banquet halls of the Hotel Societetshuset, the much altered main auditorium of The University of Helsinki and the banquet hall of the Voluntary Fire Brigade House. Symphony concerts were performed mostly in the main auditorium of the university. In other venues, the concerts usually included a popular program which consisted of orchestral music like overtures and suites with the exception of symphonies. For example, the first symphony by Jean Sibelius had its premiere in the main auditorium of the university in 1899. The second version of the work was performed the following year in the Fire Brigade House[1]. As the main auditorium of the University has been enlarged and altered after being damaged in the air raids of 1944 and the Fire Brigade House was changed to Parliament Chamber in 1907, the music of Sibelius cannot be heard in the acoustics where they were first performed. The banquet halls of the Hotel Societetshuset have also been altered or converted to other use.

The Helsinki City Museum opened an exhibition “Music! Echoes from the past of a city” on the 11th of March, 2015. The exhibition deals with the history of music in Helsinki, but instead of composers and professional musicians, the main role in the exhibition is played by the history of ordinary music lovers, listeners and enthusiasts from the city. One aim of the exhibition was to provide the visitors information on the acoustics of the concert halls from 19th century Helsinki[2]. The aim of this study was to produce this information by means of room acoustical computer modelling. The project was multidisciplinary as the geometrical models of the halls were formed using information on their architectural history. The sources used for the geometric modelling were old construction plans, photographs and seating charts. Photographs and the archival sources were included in the collections of National Archives of Finland, City Archives of Helsinki, Helsinki City Museum, Helsinki University Museum and Museum of Finnish Architecture.

2 ARCHITECTURAL HISTORY OF THE HALLS

The main auditorium of The University of Helsinki was considered the most important and dignified concert hall in Helsinki for almost 150 years after its inauguration in 1832. The auditorium, designed by architect Carl Ludwig Engel (1778–1840), was semi-circular, with a radius of about 15 meters and a height of over 14 meters (Fig. 1). The hall seated 700 people during concerts[3]. The orchestra was placed asymmetrically to the right side of hall. During the 1920’s and 1930’s, there were plans of extending the auditorium, but which were never put into practice[4-5]. The hall was seriously damaged in the air raids of the Continuation War in 1944. After the war, the hall was rebuilt and extended according to the plans of Professor J. S. Sirén (1889–1961)[6]. The alterations of the acoustics were designed by Mr Paavo Arni (1905–1969). In the renovation of 1991, the acoustics of the hall were altered again in order to achieve better speech intelligibility[7].

Another one of Engel's contributions to the musical life in Helsinki was the Hotel Societetshuset, built in 1833. The building had a large rectangular banquet hall about 30 meters long, 15 meters wide and 8 meters high. The hall included a loft for small dance orchestras. During concerts, the orchestra performed on a separate platform on the main floor. It has been said that the even 800 people could be seated in the hall[8-9]. The hotel was modernized and enlarged in the 1860s. The original hall was converted into hotel rooms, and a new hall designed by architect A. H. Dahlström (1829–1882) was built in the inner yard of the building. This new Neo-Renaissance style hall, finished in 1863, was approximately 23 meters long, 15 meters wide and about 9,5 meters high. The number of seats has been mentioned to be 1000[10], but it is obvious that the hall could not take more than 600–700 people as it was considered too small already when it was finished. Thus, the hall was enlarged in 1887 by moving the side walls six meters outwards[8-9]. Nowadays, only the roof of the original hall still remains.

The Voluntary Fire Brigade House by architect Theodor Höijer (1843–1910) was finished in 1889. The large rectangular hall of this Neo-Renaissance style building was about 22,8 meters long, 20,8 meters wide and spanned two floors (12,4 m). On the basis of the floor area, up to 1000 people could be seated in the hall. In 1907 the house was rented out to the Finnish Parliament until 1911. Later, it was used by a bank. The building was eventually demolished in 1967[11].

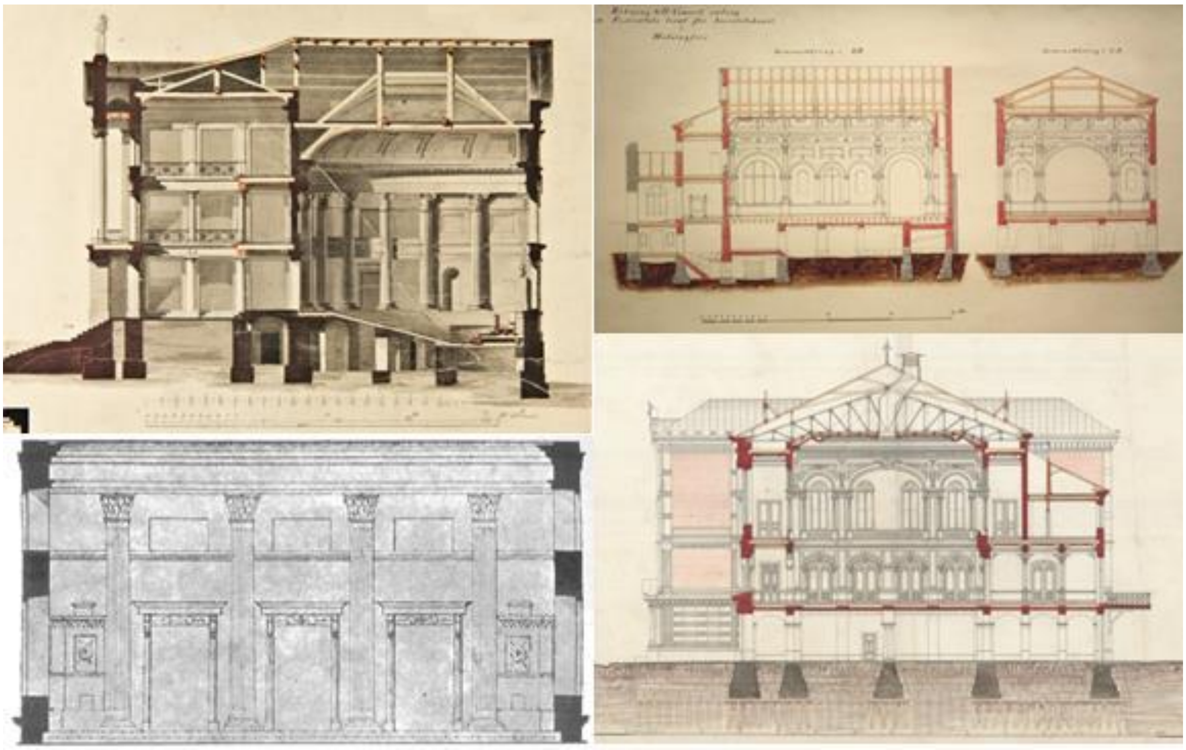

Figure 1. Examples of remaining building plans of the vanished halls. The main auditorium of The University of Helsinki (above left), the end projection of the 1st banquet hall of the Hotel Societetshuset (below left), longitudinal and cross-sections of the 2nd banquet hall of Hotel Societetshuset (above right) and the cross-section of the banquet hall of the Voluntary Fire Brigade House (below right).

3 MATERIALS AND METHODS

3.1 Overall research scheme

The geometrical models of the halls were formed on the basis of information on their architectural history. The sources used for the geometric modelling were old construction plans (Fig. 1), photographs (Fig. 2) and seating charts. Photographs and the archival sources were included in the collections of National Archives of Finland, City Archives of Helsinki, Helsinki City Museum, Helsinki University Museum and Museum of Finnish Architecture. The commercial room acoustical software Odeon Auditorium 12 was used in the room acoustical modelling.

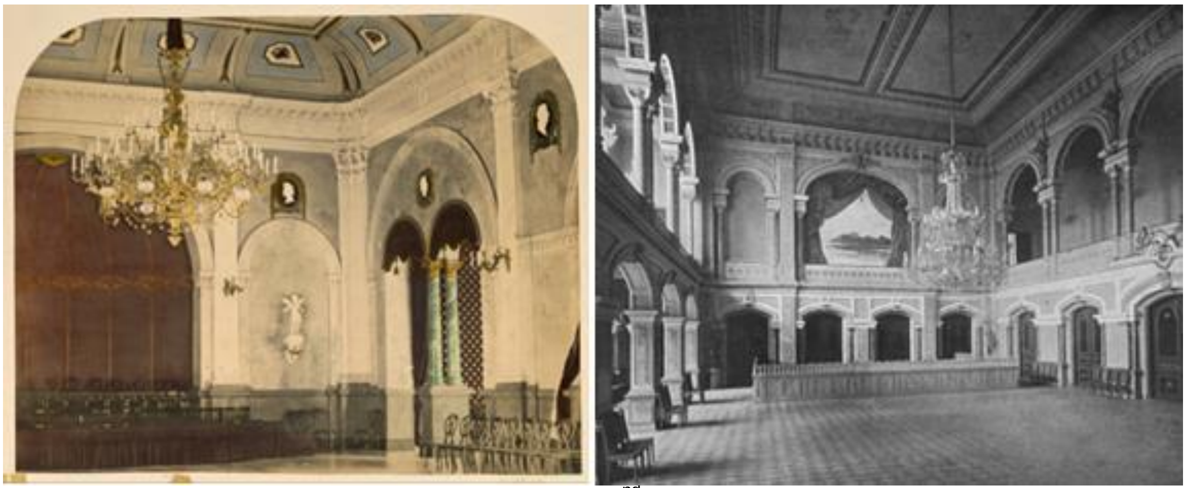

Figure 2. An artificially coloured photograph of the 2nd banquet hall of the Hotel Societetshuset (left) and a photograph of the Voluntary Fire Brigade House (right).

The research team was multidisciplinary, consisting of two acousticians, a historian and an architect. The working method was such that the historian was responsible of the studies dealing with archival sources on the geometry of the halls. The acousticians were responsible for the geometrical modelling and room acoustical modelling. The material choices of the surfaces of the halls were based on photographs and the experience of the research team's architect who is specialized in architectural history and renovation of historical buildings.

3.2 Geometrical modelling

Room acoustical modelling of a vanished building is possible provided there is enough information available on the geometry of the vanished space. There are several archival records and photographs on the main auditorium of the university and the banquet hall of the Voluntary Fire Brigade Hall. The plans of the 2nd banquet hall of the Hotel Societetshuset have also been preserved. However, the drawings were to some extent contradictory to the two existing photographs of the hall. Thus, the overall dimensions of the hall were chosen according to the building plans, but some details, such as window sizes, according to the photographs. Similar interpretations had to be done in the geometrical modelling of all halls (Fig. 3).

In the case of the 1st banquet hall of the Hotel Societetshuset, there are no known photographs of the hall and the original building plans have already disappeared in the middle of the 19th century. Before the banquet hall was converted to hotel rooms, provincial architect C. A. Edelfelt (1818–1869) created precise dimensioned drawings of Engel's work, but these have also been lost, probably in the 1980s[9]. The only remaining information of the hall's dimensions and decorations are pictures (Fig. 1) of these drawings in some publications[8-9]. The hall was a very classical shoebox-shape banquet hall, and thus it was decided that it can still be modelled in the limits of source criticism.

The geometrical models of the halls were created with the software SketchUp 2013. Instead of modelling all the decorations of the halls, the decorations have been defined as material properties of the surfaces of the halls in room acoustical modelling. Only the largest and deepest decorations have been modelled as exact shapes in the geometrical models.

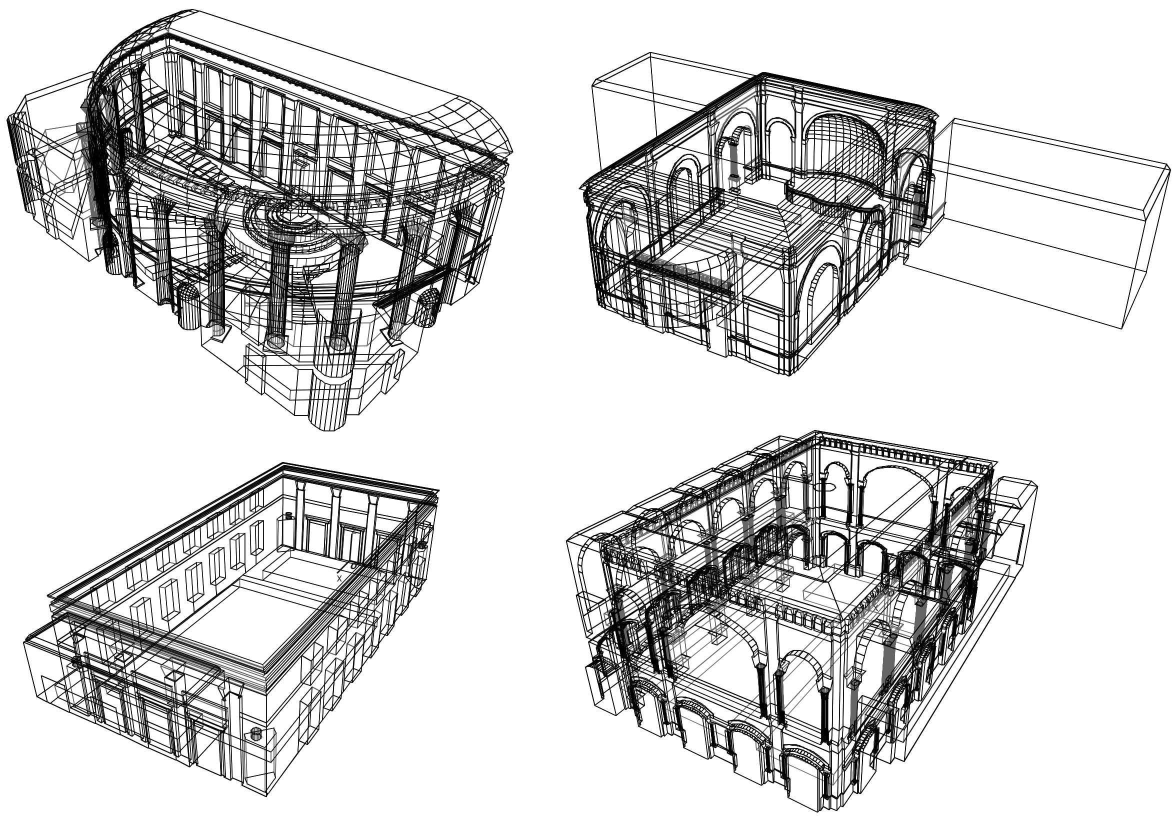

Figure 3. Geometrical models of the vanished concert halls: the main auditorium of The University of Helsinki (above left), the 1st (below left) and 2nd (above right) banquet halls of the Hotel Societetshuset and the banquet hall of the Voluntary Fire Brigade House (below right).

The subjective and objective acoustical properties of concert halls depend on their volume and shape, as well as the material properties of their surfaces. The volume V [m^3], and primary dimensions length L [m], width B [m] and height H [m] of the modelled halls have been presented in table 1. Generally the most important absorbing surface in the hall is the audience or seating area. It is recommended that the volume of a concert hall should be around 10 m^3 per seat[12]. Nowadays, audience areas are designed so that there are two seats per square meter[13]. By studying the audience area of the halls, it could be seen that in 19th century Helsinki, the audience was seated more densely, with around 2.5 seats per square meter. Therefore, the relation of the volume and seats is not comparable with the present halls. In regards to room acoustics, the acoustical audience area S_A is considered more important than the amount of seats[12-14]. The relation V/S_A is therefore considered more comparable between different halls (Table 1).

Table 1. Main dimensions of the studied concert halls in 19th century Helsinki.

Hall	***L* [m]**	***B* [m]**	***H* [m]**	**V [m^3]**	**Seats**	**V/S_A [m]**
University	30,3	17,2	14,4	5260	ca 700	24,8
Hotel Societetshuset 1	30,7	15,0	8,0	3680	ca 800	17,7
Hotel Societetshuset 2	25,8	14,2	9,5	3480	ca 600–700	22,9
Fire Brigade House	22,8	17,4	12,4	4740	ca 1000	19,8

3.3 Room acoustical modelling

The room acoustical modelling was carried out with the commercial modelling software Odeon Auditorium 12. In concert halls, the most important absorbing surface is the audience area. Contrary to present-day concert halls where the concert and rehearsal situations should not differ from each other, the acoustics of the 19th century concert halls changed because the seats were wooden or only moderately upholstered. Therefore, each hall was modelled in two situations: a concert situation with a full audience and a rehearsal situation with empty seats. Values measured by Beranek and Hidaka[15] were used as absorption coefficients (Table 2). The scattering coefficients were chosen according to Christensen & Rindel[16] and Zeng et al[17]. The audience area was modelled as 0.8 m high box (Fig. 4.).

Table 2. Absorption coefficients used in room acoustical modelling.

Surface	**125 Hz**	**250 Hz**	**500 Hz**	**1000 Hz**	**2000 Hz**	**4000 Hz**
Full audience	0,51	0,64	0,75	0,80	0,82	0,83
Empty seats	0,35	0,4	0,41	0,35	0,33	0,27
Windows	0,35	0,25	0,18	0,12	0,07	0,04
Doors	0,14	0,10	0,06	0,08	0,10	0,10
Painted plastered brick	0,02	0,02	0,03	0,04	0,05	0,05
Columns	0,02	0,02	0,03	0,04	0,05	0,05
Roofs	0,19	0,14	0,09	0,06	0,06	0,05
Floors	0,15	0,11	0,10	0,07	0,06	0,07
Orchestra podium	0,18	0,12	0,10	0,09	0,08	0,07
Statues, tiled stoves	0,01	0,01	0,01	0,01	0,02	0,02

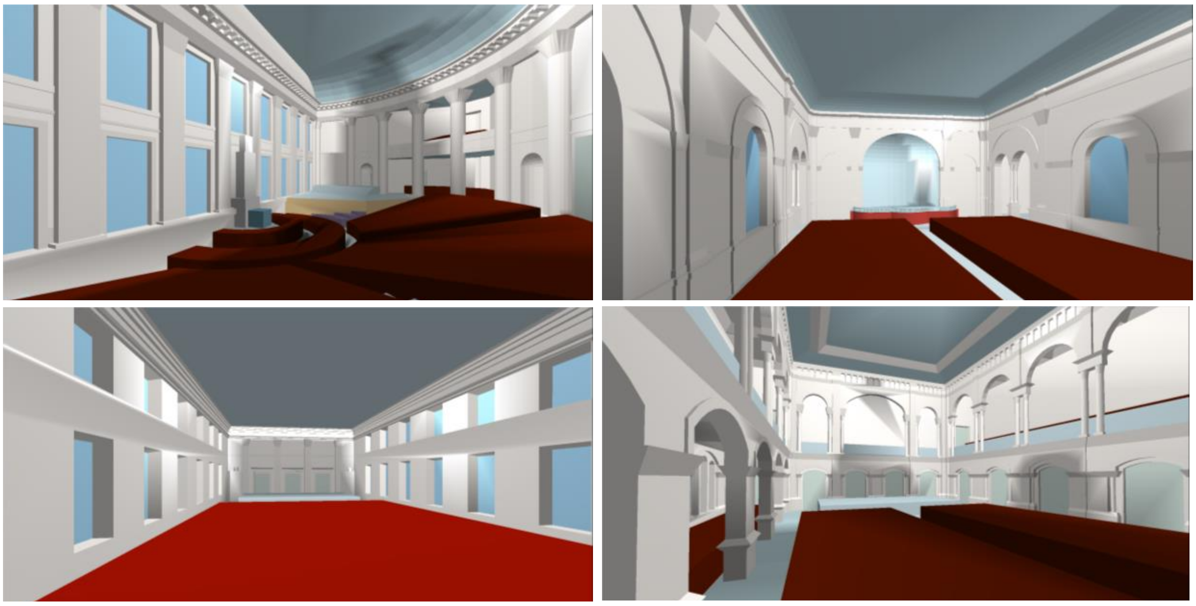

Figure 4. Views from the room acoustical models of the main auditorium of the university (above left), the 1st (below left) and 2nd (above right) banquet halls of the Hotel Societetshuset and the banquet hall of the Voluntary Fire Brigade House (below right).

The sound source used, was an omnidirectional point source located at the center of the podium at a height of 1.5 m according to the standard ISO 3382-1[18]. The were receivers located 0.4 m over the 0.8 m high audience box and were placed in a 0,5 m grid in the audience area (Fig. 5). The following room acoustical parameters were calculated: reverberation time T_{30}, early decay time *EDT*, clarity C_{80}, strength *G* and lateral energy fraction LF_{80}. The values of these parameters are shown in the octave bands 125 Hz, 250 Hz, 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz.

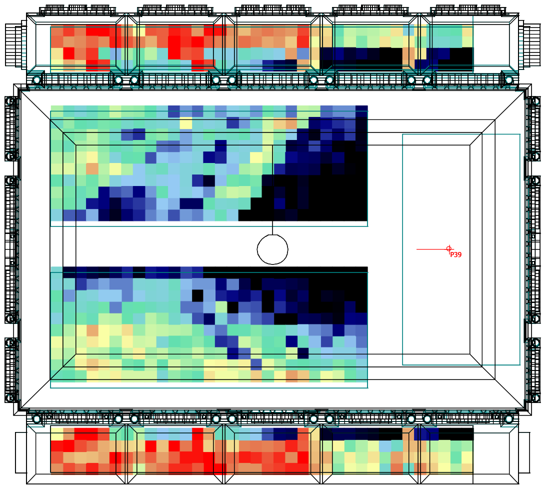

Figure 5. An example of the distribution of the lateral energy fraction at 1000 Hz in the hall of the Voluntary Fire Brigade House. Colour scale: black = < 0,15, red = > 0,30.

4 RESULTS

A receiver grid makes it possible to calculate a distribution of the room acoustical parameters as a result of the modelling. In tables 3 and 4, the mean values of the room acoustical parameters are shown as well as the fractiles of 10 % and 90 %. According to ISO 3382-1[18], the values of T_{30}, *EDT*, C_{80} and G have been given as mean values of octave bands of 500 Hz and 1000 Hz. The values of LF_{80} have been given as mean values of octave bands 125–1000 Hz. The modelled reverberation times have also been presented at octave bands in figure 6.

Table 3. Modelled room acoustical parameters with a full audience. The bolded value shows the mean value, the left number the 10 % fractile and the right number the 90 % fractile.

Parameter	University	Hotel Societetshuset 1	Hotel Societetshuset 2	Fire Brigade House
T_{30} [s]	1,9…**2,0**…2,0	1,6…**1,6**…1,6	1,8…**1,9**…1,9	2,0…**2,0**…2,1
EDT [s]	1,8…**2,0**…2,1	1,5…**1,6**…1,6	1,5…**1,6**…1,7	1,8…**2,0**…2,0
C_{80} [dB]	-2,7…**-0,6**…1,7	-0,6…**0,2**…1,0	-0,6…**1,3**…2,8	-3,0…**-0,7**…0,8
G [dB]	6,2…**8,4**…9,8	8,7…**9,8**…11,7	10,5…**11,2**…11,9	7,3…**9,0**…10,6
LF_{80}	0,10…**0,22**…0,33	0,21…**0,25**…0,27	0,11…**0,18**…0,23	0,17…**0,25**…0,33

Table 4. Modelled room acoustical parameters with empty seats. The bolded value shows the mean value, the left number the 10 % fractile and the right number the 90 % fractile.

Parameter	University	Hotel Societetshuset 1	Hotel Societetshuset 2	Fire Brigade House
T_{30} [s]	2,7…**2,7**…2,7	2,2…**2,2**…2,2	2,4…**2,4**…2,4	2,8…**2,8**…2,9
EDT [s]	2,6…**2,7**…2,9	2,2…**2,2**…2,3	2,1…**2,3**…2,4	2,7…**2,8**…2,9
C_{80} [dB]	-4,6…**-2,6**…-0,5	-2,8…**-2,1**…-1,1	-2,3…**-1,0**…0,7	-5,1…**-2,9**…-1,0
G [dB]	8,8…**10,6**…11,8	11,9…**12,6**…13,8	12,6…**13,2**…13,8	9,8…**11,3**…12,5
LF_{80}	0,11…**0,22**…0,33	0,22…**0,25**…0,28	0,12…**0,18**…0,24	0,18…**0,26**…0,33

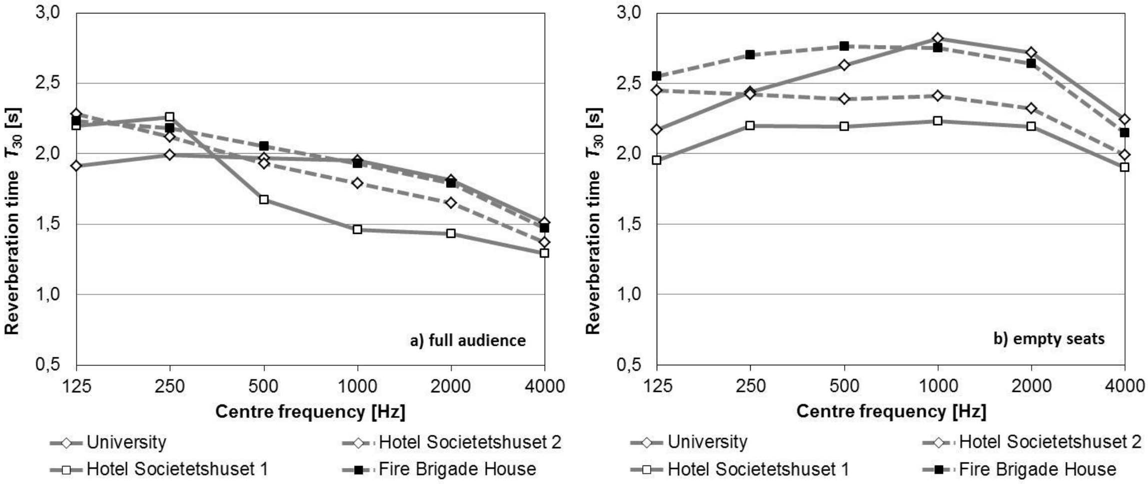

Figure 6. Modelled reverberation times T_{30} [s] with a full audience (left) and empty seats (right).

5 DISCUSSION AND CONCLUSIONS

All of the studied concert spaces were small compared with those built during the same century in Central Europe, the largest of which could seat more than 2000 people[12,14]. Regarding the number of seats, the Finnish concert halls of the 19th century would probably be classified as chamber music halls. However, their acoustics differs from chamber music halls. For example, T_{30} and *EDT* are similar to the values of much larger halls. According to Barron[12] and Beranek[14], the relation of volume and acoustical audience area V/S_A is usually 13–24 m in the large concert halls. This parameter is inside the given scale in the studied halls, too. This also means that the studied halls have been reverberant enough and suitable for the performance of symphonic music.

On the other hand, the studied halls were similar to present small Finnish concert halls with around 400–700 seats. In the present small concert halls, the value of strength *G* is typically between 6 and 12 dB[19], similar to the studied halls. Even though the studied halls were reverberant enough for symphonic music of the Classical and the Romantic era, the performances might have been excessively loud when the size of the orchestras in Helsinki started to grow during the last decades of the 19th century. Another common feature in all halls is the large difference between the concert and rehearsal situation; the latter being much more reverberant.

There were also differences between the studied halls. The architectural solution of the main auditorium of University of Helsinki was exceptional regarding concert use: the orchestra podium was in the corner of the semicircular auditorium. The audience sitting in the opposite end against the orchestra received very strong reflections from the outer wall of the hall in the left, but the reflections from the right were absorbed by the audience sitting in the raising rows of the auditorium. Close to the orchestra, the situation had been similar if the listener turned their head towards the orchestra. There were also large differences between the seats in different parts of the hall.

The first hall of the Hotel Societetshuset was the closest example of a classical shoebox-shaped hall. The differences between the seats were the smallest of the studied halls. The hall was relatively low, which resulted in the shortest reverberation time. The height was, however, large enough to allow the first reflections to arrive from the side. On the basis of reverberance, this hall was the closest to a chamber music hall.

Usually values of C_{80} correlate strongly with reverberation time. In the second hall of the Hotel Societetshuset, the clarity value was clearly larger than in the main auditorium of the university or the fire brigade hall even though these three halls were equally reverberant. The *EDT* value had the largest differences from T_{30} in this hall and there were large deviations between the seats in the value of lateral energy fraction LF_{80}. One explaining factor to these phenomena is the openings to ladies' and gentlemen's salons in the front of the hall. Part of the sound travels to the salons and is absorbed there, which results in weak lateral energy especially in the front part of the hall. This also explains the short early decay times.

The hall of the Voluntary Fire Brigade House was asymmetric on the bottom floor. The asymmetrical layout probably caused a horizontal image shift on the floor seats, and the clarity was somewhat poor on the balconies. However, the overall reverberation and diffusivity of the hall can be judged as favorable for symphonic music.

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