European Timber Sound Insulation Atlas

Hansueli Schmid
Moritz Späh
Noemi Martin
Klaus Naßhan

Report no STB03 WG3
RISE Report 2017:58

SILENT TIMBER BUILD

RISE Research Institutes of Sweden AB

RISE Rapport :2017:58
ISBN: 978-91-88695-25-3
Göteborg

Table of Contents

1 Description of the Project: WP 3: European Timber Sound Insulation Atlas

The objective of this work package is to provide an acoustic performance knowledge database of European timber building constructions. In a first step a methodology for structuring the planned data base will be developed. The database will be fed with existing examples from the different European timber building regions. These examples will be grouped into similar solutions and sound insulation performance. After reprocessing the data the different construction systems will be optimized in WP 2.
An interface to the broad public of the database will then be developed. This user friendly and appealing front-end of the European Timber Sound Insulation Atlas (EATSI-Atlas) will provide information on various evaluation criteria, including expected future European target values.

Everything will be provided to the broad public. In order to enhance the possibilities of SME’s being able to meet the acoustic performance requirements for the future there will also be “hints” on simplifying junction model data for prediction and evaluation for innovative timber based building constructions.

The work package includes four tasks.

- Task 1 comprises data collection from different wood based building constructions of European regions, provided by project partners.
- Task 2 implies grouping of the collected systems by their construction type.
- Task 3 is the development of the web database (after grouping etc.). The EATSI-Atlas will be programmed in order to facilitate future developments of new systems through simply adding them to the database back-end.
- Finally task 4 includes the development and implementation of an auralization tool to the atlas for easy understanding of what can be expected, by listening to audio recordings.

Principles are given in Figure 1 below.

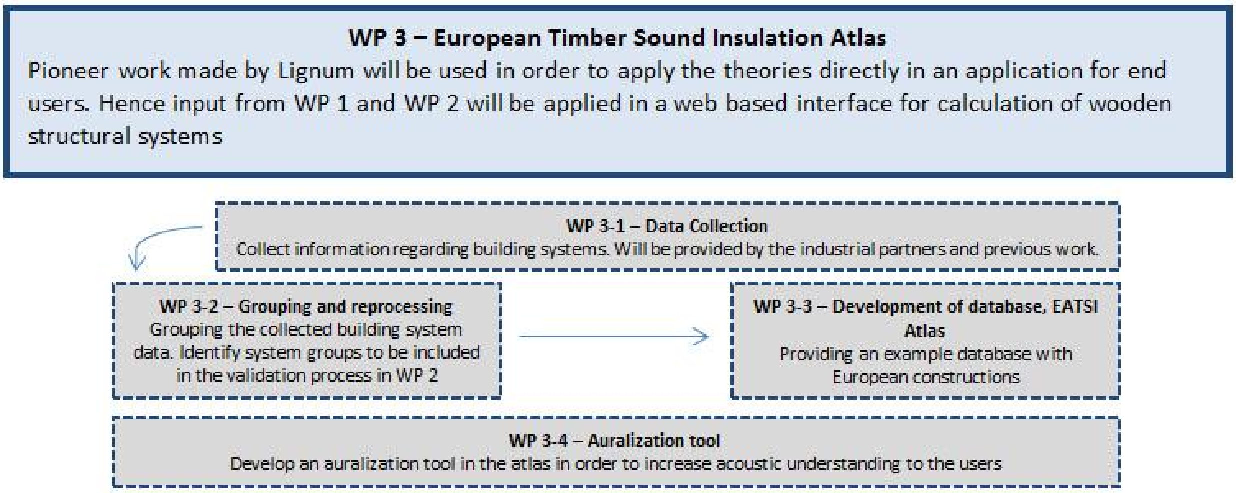


Figure 1: The database and Institutions involved

In brief, the campaign will include the following activities:

- Collection of building-systems data from different countries. The data will be provided by the companies involved, wooden industries and consultants.
- Extensive grouping and selection of building systems by types, such as volume elements, flat elements etc. and in relation to their build-up, such as CLT, beams or any other build up.
- Selection from the grouping of typical European systems for the prediction and validation according to WP 1 and 2.
- Reprocessing of the data according the results of WP 1 and WP 2 and develop of simplifications to selected systems.
- Development and implementation of an auralization tool for the 'European atlas' improving understanding and accessibility for a broad public.

The innovative European sound insulation atlas will be an outstanding tool for the future development of competitive wood based construction systems for the different European regions. It will also serve as the backbone for the prediction of the acoustic behavior between different rooms etc., by consultants, industry and product developers in practice.

Within the atlas, the data's quality will be distinguished, ranking between full spectrum data, part spectrum data, single number data, laboratory measured data, on site measured data, calculated data and estimated data, if applicable. Missing data will be defined and determined in WP 2. A further criterion is the quality of the specific boundary conditions. After the data-screening, the relevant data is filled into the European Atlas Timber Sound Insulation's back-end. In task 2 the existing systems will be grouped to similar solutions. Depending on the results of the other WP's it will be decided, which systems are selected and which modifications have to be done to provide full spectrum sound insulation including the low frequency range for different levels. The chosen systems will be the basis for the calculation models of WP 1 and also for the validation procedure in WP 2.

The database will also include the necessary provisions for simple and robust systems and future continuous development of single number descriptors, the low frequency range and the flanking transmission, depending on type of housing unit (e.g. student, elderly, "normal" families). The data base shall provide a single point of access data storage for European wood based construction systems and will provide to get the necessary data for a successful building acoustic design process.

Finally in task 4 an auralization tool will be developed. Auralization is an electronic simulation of sound signals for arbitrary types of excitation and for all kind of building constructions [31 – 34]. This tool uses the data in the EATSI-Atlas to give an audible impression of the different sound insulation effects provided by the different European wood based building constructions. Through this tool the dissemination of results (WP 4) can be demonstrated to interested people that are not acousticians.

[31] Naßhan, K.: Bauakustische Auralisation in Echtzeit. IBP-Mitteilung 26 (1999) Nr. 348 des Fraunhofer-Instituts für Bauphysik.
[32] Naßhan, K.: Auralisationsprogramm zur Demonstration bau- und raumakustischer Wirkungen von Bauteilen. IBP-Mitteilung 27 (2000) Nr. 365 des Fraunhofer-Instituts für Bauphysik.
[33] Naßhan, K.; Maysenhölder, W.: Mit Auralisation und rechnerischen Prognoseverfahren zur optimalen Schalldämmung. Bauphysik 23 (2001) H.2, 76-80.
[34] Naßhan, K: Auralisation mit Tabellenkalkulationsprogrammen. Fortschritte der Akustik: DAGA 2005, München, S. 317-318.

1.1 Goals

- Make test documents accessible

- Overview of solutions
- Filtering function
- Multi language
- Automatic Image and Datasheet
- Automatic description text
- Comparing different values in one graphic

2 The European timber component catalog for sound insulation

The European timber component catalog is currently primarily a tool for the calculation of the acoustic properties of buildings made of wood and provides sound characteristics of components. It is the result of several years of work within the framework of the Swiss project <Sound insulation in timber construction> in association with the EMPA and the Bern University of Applied Sciences, architecture, wood and construction and a multitude of industrial partners as well as the silent timber build project. The timber component catalog is the central control element for the collection and dissemination of components and test reports within the projects.

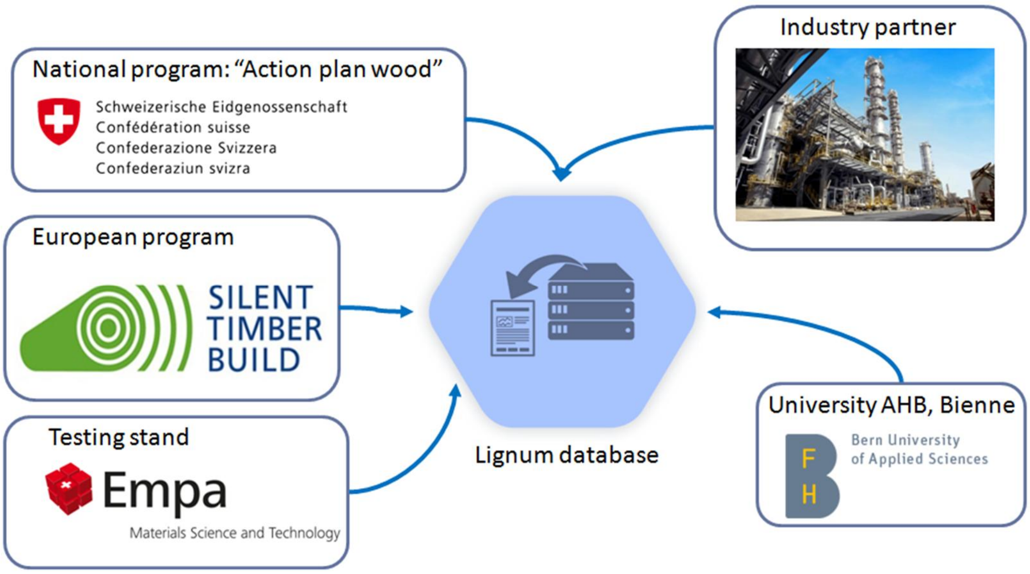


Figure 2: The database and Institutions involved

2.1 Integrated user interface

- The European component catalog, is distinguished by a well thought-out and clear presentation. (Integrated design)
- The filter functions and the solid and material-specific representation of the components offer a high user-friendliness.
- Thanks to multilingualism, woodworkers all over the world can benefit from the knowledge they provide.

2.2 Integrated data management

In the first version the component group <ceilings> was put online in 2014. In the meantime, the construction industry has begun to use BIM in the course of time. Therefore, components 2015 were decomposed into individual materials (decomposition) and reassembled into functional layers (aggregation) as components.

- Components are made of generic materials. (Abstraction)
- A material is only recorded and maintained once. (Integrated information). Everything is displayed uniformly.
- Already programmed functions can be used for other components / products.
- Simple translation into other languages thanks to a decomposed data base
- Consideration of the levels of detail in the planning: <From general to special>. From the generic material to the specific producer product. (From LOD 300 to LOD 400)

2.3 Dissemination of the data

The project partners have selected the components shown public view. In addition, Lignum additionally verified the sound insulation values of these components with various measurements and calculations. With a login for specialists, further components with test reports and sound attenuation curves of prognosis models are visible. The view for specialists shows a much larger number of components; The sound attenuation curves of different prognosis or rake models are compared graphically with those of measurements.

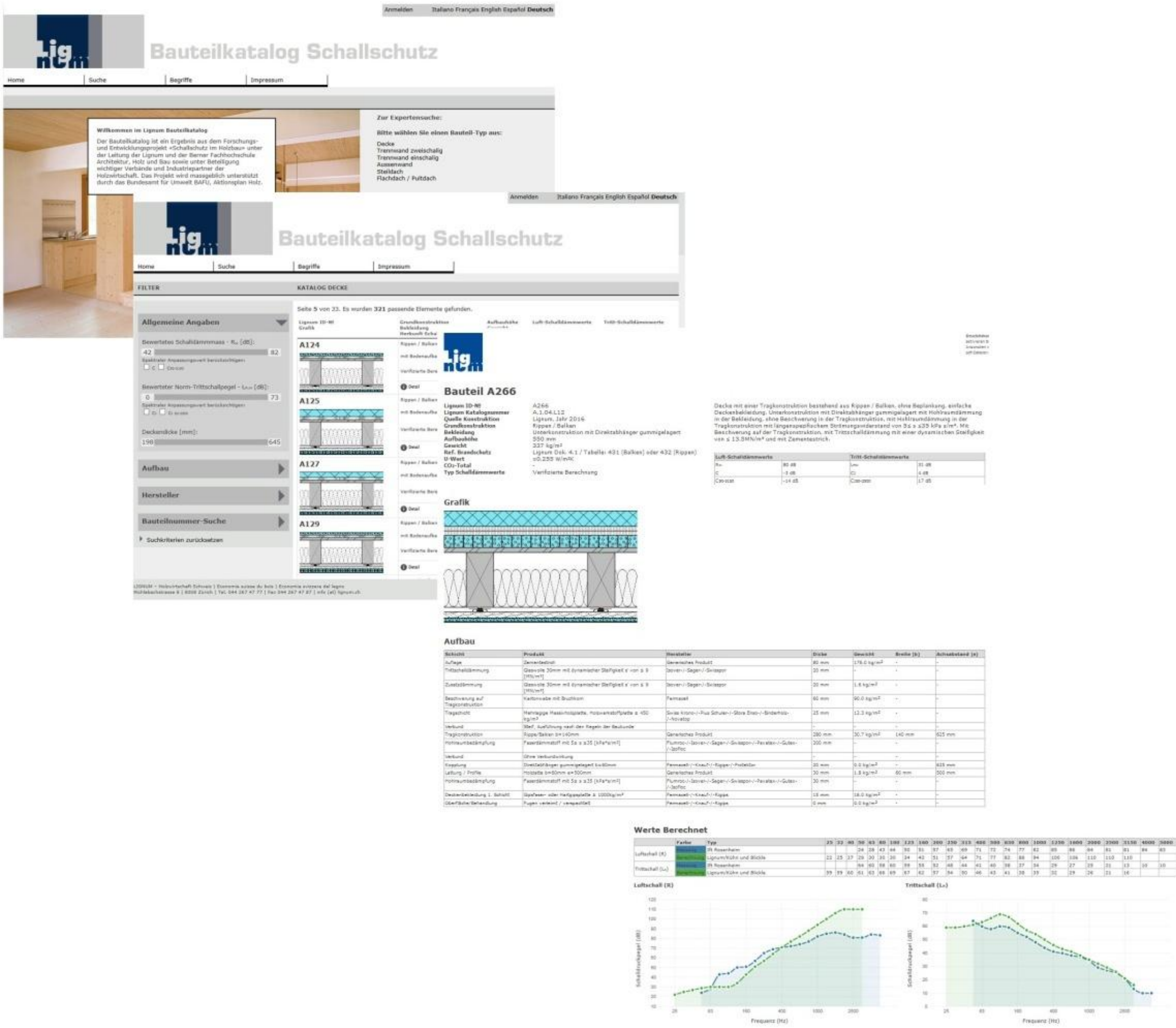


Figure 3: Levels of information depth www.lignumdata.ch

2.4 What the European component catalog offers today

- Domain www.lignumdata.ch
- 9 languages: German, French, Italian, English, Spanish, Japanese, Russian, Swedish, Finnish
- 6 component groups: ceilings, partition walls single-walled, partition walls double-walled, exterior walls, Steep roof and Flat roof
- Filter options for a specific search for component set-up, characteristic values, manufacturer, component number
- Scale-generated component diagrams: 1 pixel = 1mm
- Detailed component description, which is automatically generated in all languages, with design requirements and minimum material requirements
- Specification of sound insulation level, standard impact sound level, spectrum adaptation values
- Linear components with additional specification of width (b) and center distance (e)
- Symbols for the connection of claddings and structures: rigid, stiff or without a composite

effect
- Differently colored component layers according to VKF fire behavior groups
- Direct reference to the relevant table in the Lignum fire protection documentation 4.1 <Components in wood - ceilings, walls and cladding with fire resistance>, edition 2015
- Multiple login levels with different information width and depth; Standard: Components approved by Lignum
- In the background accessible test reports with sound attenuation curves of prognostic models (with specialist login)
- Materials are colored in the graphic. Life cycle assessment data can also be added later.

Figure 4: European component catalog on the screen

Table 1: Number of components in the database

	Floor constructions	Partition single shell	Partition double shell	Outer wall	Steep roof	Flat roof
Components released for specialists	1973 pcs.	240 pcs.	322 pcs.	941 pcs.	140 pcs.	22 pcs.
Components released public	237 pcs.	43 pcs.	8 pcs.	44 pcs.	27 pcs.	0 pcs.

2.5 Component Types

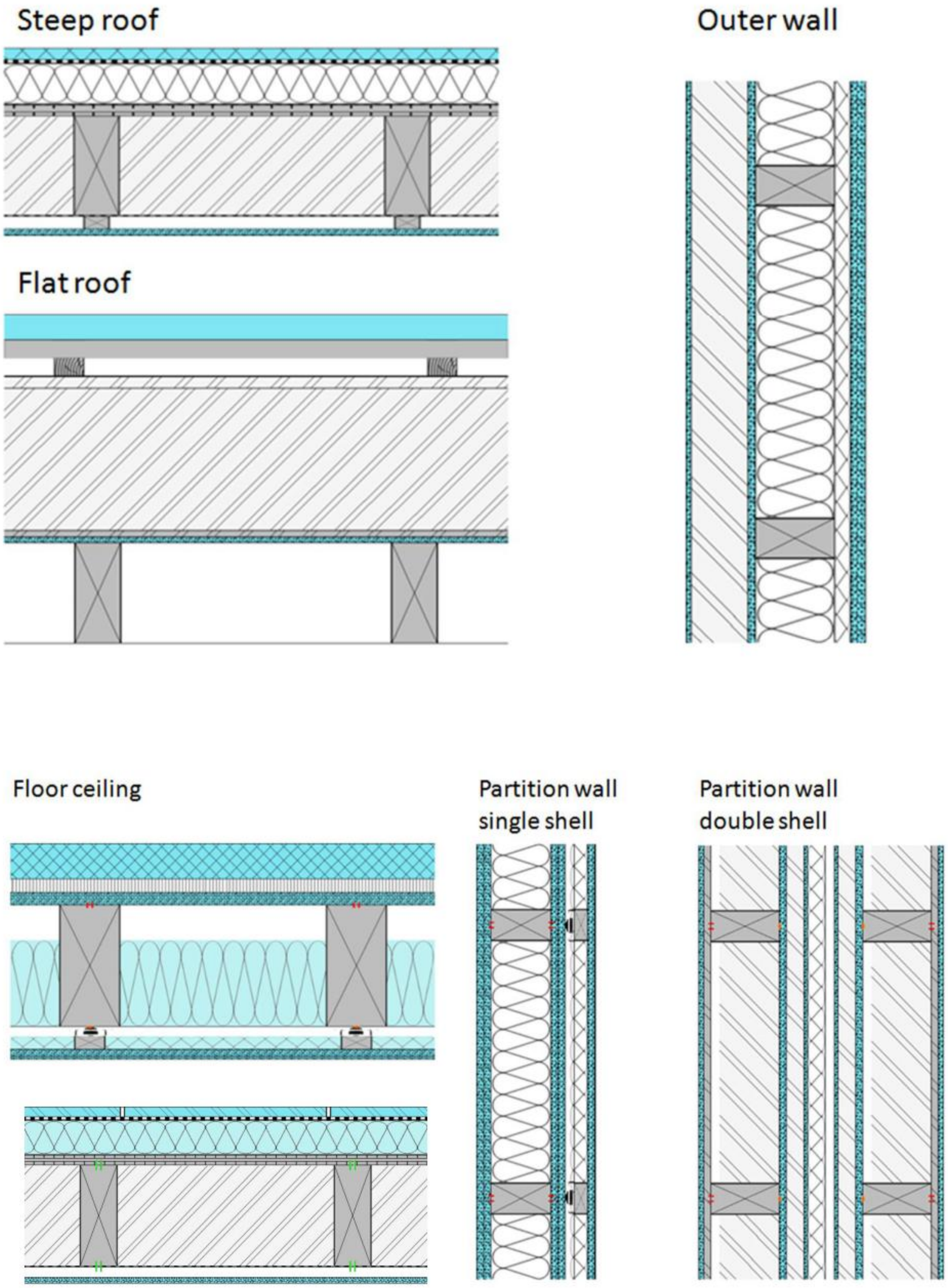


Figure 5: Component Types

2.6 Category overview

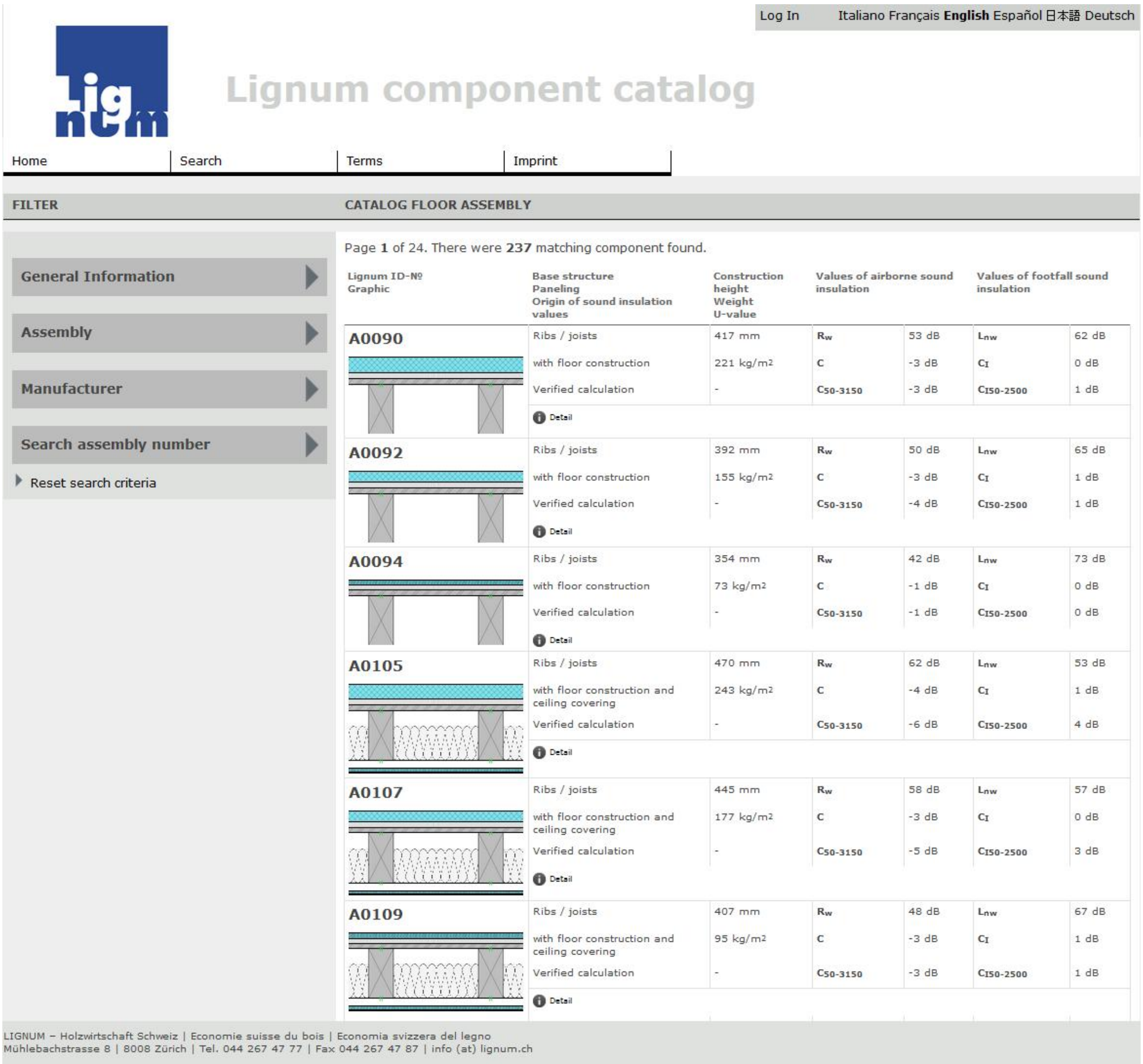


Figure 6: Overview component type: ceiling construction

2.7 Detail view

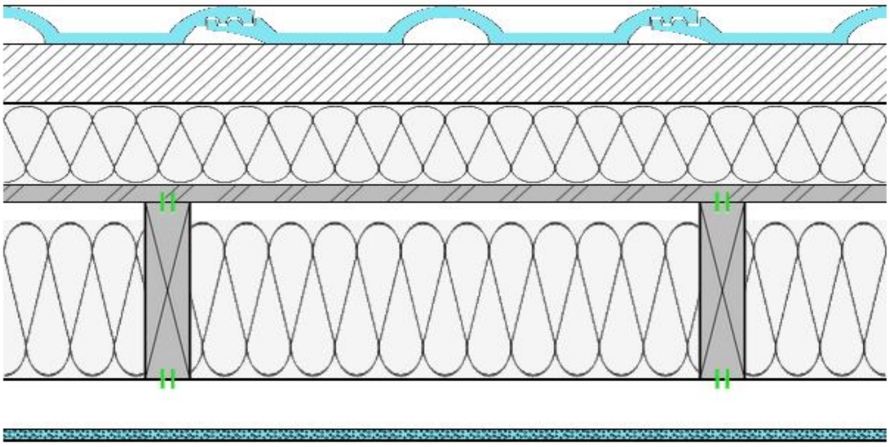
Construction assembly E0146

Lignum ID-№	E0146
Lignum Catalog number	E.1.05.T7
Source of construction assembly	FCBA N° FDE: B00900, Year 2013
Base structure	Ribs / rafters
Sheathing	Sheathed on one side
Paneling	Simple covering
Construction height	530 mm
Weight	90 kg/m²
Reference fire protection	VKF 14-15, Kap. 3.3 / Lignum Doc. 2.1, Kap. 6
U-value	-
CO_2-Total	-
Type sound insulation	Calculation without verification , Measured values

Steep roof consisting of a basic construction of ribs / rafters with cavity insulation in the supporting structure with air flow resistivity [r] of 5≤ r ≤35 kPa s/m². Sheathed on the leftside. Simple covering, with insulation on top of the sub-floor.

Values of airborne sound insulation	
Rw	62 dB
C	-
Ctr	-11 dB

Graphic



Assembly

Layer	Product	Manufacturer	Thickness	Weight	Width (b)	Axial distance (e)
Roofing	Roof tiles	Generisches Produkt	47 mm	40.1 kg/m²	-	-
Battens / profiles	Wood laths 48x48 + roof laths 48x24mm e=350mm	Generisches Produkt	72 mm	2.8 kg/m²	50 mm	625 mm
Under the roof	Roofing underlay	Generisches Produkt	0 mm	0.1 kg/m²	-	-
Exterior insulation layer 1	Mineral wool ≥ 160kg/m³	Flumroc-/-Isover-/-Sager-/-Swisspor	100 mm	12.0 kg/m²	-	-
Sub-floor	Chipboard	Generisches Produkt	19 mm	11.4 kg/m²	-	-
Bond	Stiff, execution of the prior art.		-	-	-	-
Supporting structure	Rib/bar b=45mm	Generisches Produkt	220 mm	8.1 kg/m²	45 mm	600 mm
Cavity dampening	Mineral wool	Generisches Produkt	200 mm	4.0 kg/m²	-	-
Bond	Stiff, execution of the prior art.		-	-	-	-
Vapor barrier	Vapor barrier polyethylene (PE)	Generisches Produkt	0 mm	0.2 kg/m²	-	-
Battens / profiles	Wood lath b=38mm	Generisches Produkt	60 mm	2.2 kg/m²	38 mm	500 mm
Covering below 1st layer	Plasterboard type A	Knauf-/-Rigips	13 mm	9.2 kg/m²	-	-
Surface below	Glued joints/smoothed	Fermacell-/-Knauf-/-Rigips	0 mm	0.0 kg/m²	-	-

Calculated values

	Color	Type	25	32	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
Airborne sound (R)	Measurement					23	20	23	32	41	43	51	56	56	57	63	68	70	74	77	80	82	81	82	86	88
	Calculation	Lignum/Kühn and Blickle	16	18	20	22	24	24	23	26	36	43	50	57	63	70	75	81	86	92	99	105	110	110		

Airborne sound (R)

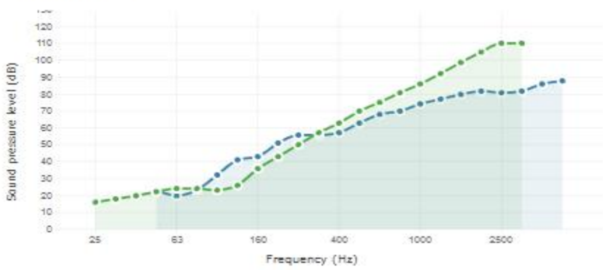


Figure 7: Detail view

2.8 Filters

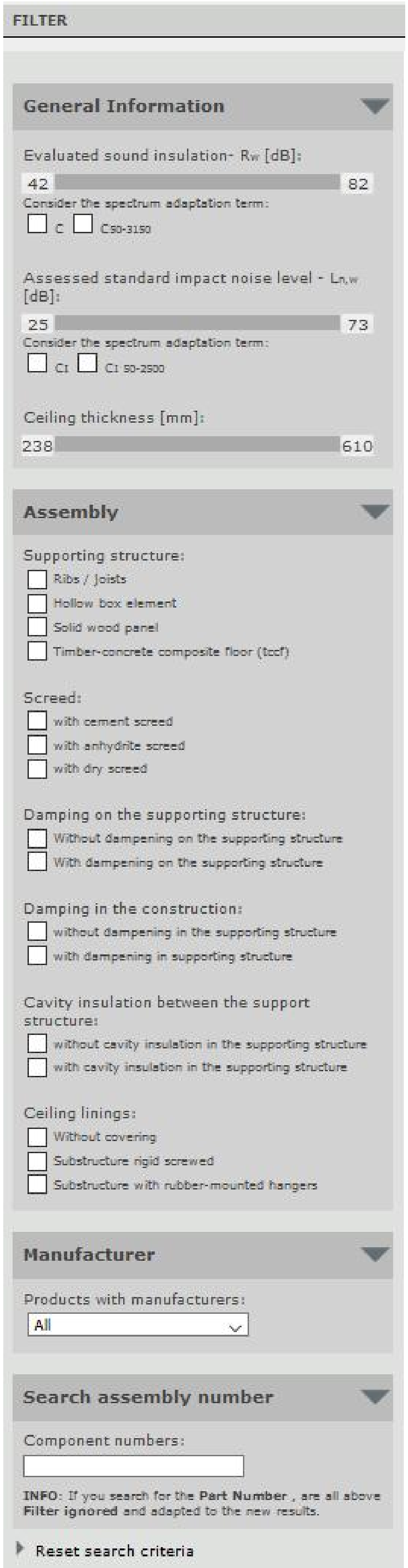


Figure 8: Filter functions for ceiling

2.9 Automatic Standard calculation according formula Kühn & Blickle

2.9.1 *Calculation model Kühn & Blickle [4]*

Measurements of wood floors show typical frequency response; very high airborne sound levels in the frequency range between 16 Hz and 160 Hz; Strongly decreasing air sound levels with an increasing frequency above approx. 125 Hz. This means that for the assessment of wooden ceilings, the low-frequency range is primarily decisive. As computational investigations show, it is sufficient for the determination of the important kinetic parameters $L_{n,W}$ and C_I to be completely taken into account from the low-frequency frequency range up to f = 200 Hz, while the air sound levels at the higher frequencies must not be taken into account. In the case of ready-to-use floor coverings (ceilings with dry floor, cement floor, etc.), the fault occurring with this restricted approach is at a maximum of 1 dB.

Due to the possibility of limiting the frequency range to 200 Hz, a simplified calculation model has been developed which allows to determine both the walking noise level LG and the standard acoustic sound level L_n of wooden floors with sufficient accuracy:

$$L_G(f) = L_{no} + 20\log\left[\left|\frac{Z_{Bo}}{Z_B + Z_M}\right|\right] - 9\log\left[\frac{\left(1-\left(\frac{f}{f_{od}}\right)^2\right)^2 + d_d}{1+d_d}\right] - 5\log\left[\frac{\left(1-\left(\frac{f}{f_{ob}}\right)^2\right)^2 + d_b}{1+d_b}\right] + \Delta L_G(f) \quad [dB]$$

Formula 1: Formula Kühn & Blickle

2.9.2 *Meanings here:*

L_{no}: Standard sound level of a fictive standard ceiling, consisting of 22-25 mm thick wood chipboard or MDF boards, connected non-positively with wooden beams (see drawing at the back):

Table 2: Standard sound level of a fictive standard ceiling

Frequency f 16	20	25	31,5	40	50	63	80	100	125	160	200	(Hz)
L_{no} 75,0	76,0	76,0	76,5	77,0	77,0	77,5	78,0	79,0	82,5	83,0	83,0	(dB)

(Note: The above L_{no}- Values are empirical values)

Z_{Bo}: Input impedance Wooden beam of the reference ceiling:

$$Z_{Bo} = 2{,}67 \cdot \rho_o \cdot H_o \cdot B_o \cdot \sqrt{c_o \cdot H_o \cdot f}\left(1+i\right)$$

ρ_o: Density of wood;

H_o: beam height = 0,20 m;

B_o: beam width = 0,12 m;

c_o: Stretch-wave speed of the wood = 2500 m/s;

i Imaginary unit

Z_B: Entrance impedance of the wooden beams of the floor.

$$Z_B = 2{,}67 \cdot \rho \cdot H \cdot B \cdot \sqrt{c \cdot H \cdot f}\left(1+i\right)$$

Z_M: Entrance impedance of the floor:

$$Z_M = 2{,}67 \cdot e \cdot \sqrt{c \cdot H \cdot f} \cdot \left(m_{b1}+m_{b2}\right) i$$

(e: Axial distance between the wooden beams; m_{b1}: Area-related mass of the walking layer (dry ground, backing floor, etc.); m_{b2}: Surface-related mass of wood chipboard or MDF boards on the wooden beams, including a load placed on it (concrete slabs, screed))

f_{od}: Mass-spring-mass resonance of the ceiling panel below the wooden beams

$$f_{od} = 161 \cdot \sqrt{s_d \cdot \left(\frac{1}{m_{d1}} + \frac{1}{m_{d2}}\right)} \; [Hz]$$

(s_d: Dynamic stiffness of the air cushion incl. m_{d1} area-related mass of the suspended ceiling; $m_{d2:}$ corresponds in the normal case of the vaule m_{b2}, **Exception: wooden beams with intermediate floor and onlying screed**)

d_d: Loss factor of the air cushion including insulation material laid therein (d_d = 0,3 - 0,5)

f_{ob}: Mass-spring mass resonance of the applied dry floor, cement floor, etc., including the influence of a weight laid underneath (concrete slabs, bed):

$$f_{ob} = 161 \cdot \sqrt{s_b \cdot \left(\frac{1}{m_{b1}} + \frac{1}{m_{b2}}\right)} \; [Hz]$$

(s_b: Dynamic stiffness of the insulation layer under the dry floor, cement floor, etc.)

d_b: Loss factors of the insulation layer under the dry floor, cement floor

(d_b = 0,1 - 0,4)

ΔL_G (f): Correction for the calculation of the noise level in the reception area (instead of the standard sound level) L_n):

f	16	20	25	31,5	40	50	63	80	100	125	160	200	(Hz)
ΔLG	0	0	0	0	0	-3,0	-7,5	-12,0	-16,5	-21,0	-25,5	-30,0	(dB)

Note: When calculating the standard acoustic sound level L_n, the correction values L_G (f) are eliminated.

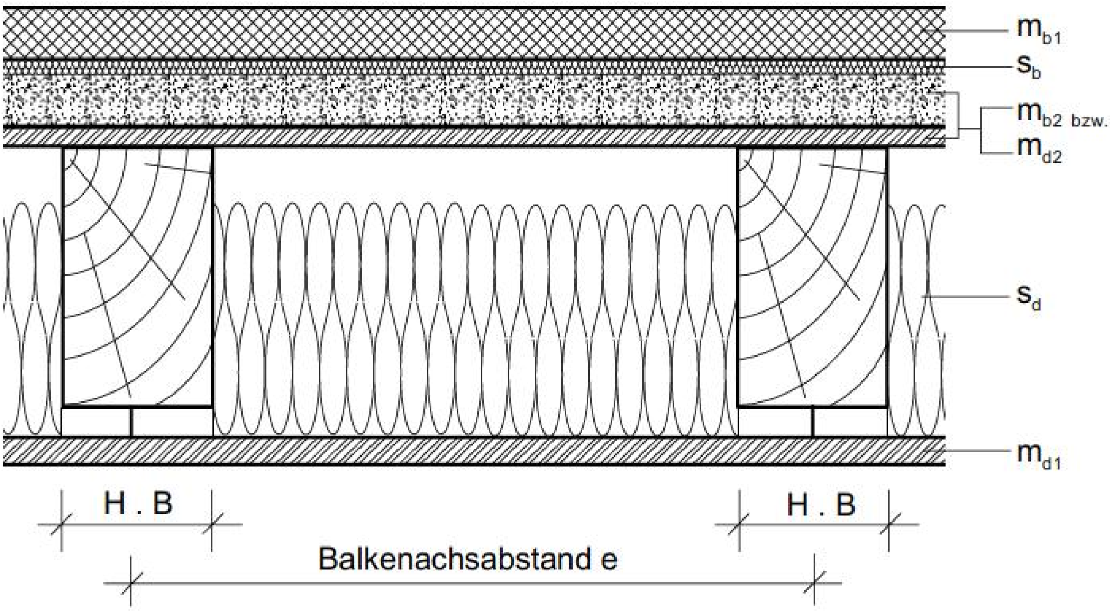


Figure 9: Section through floor slab with registered sizes

The following assumptions were made during the development of the calculation model:

- the wood chipboard or MDF boards laid on top are connected to the wood beams (glued or screwed at a distance of 300 mm);
- the suspended ceiling cladding is attached to the wooden beams by means of spring rails or spring clips;
- the cavity above the ceiling panel is filled with insulating material at least 2/3 of its height (stone wool or glass wool or flocculated);
- the impact sound transmission takes place to the main over the floor (sub-transmission is subordinate).

2.9.3 Assignment of mass according definition in formula

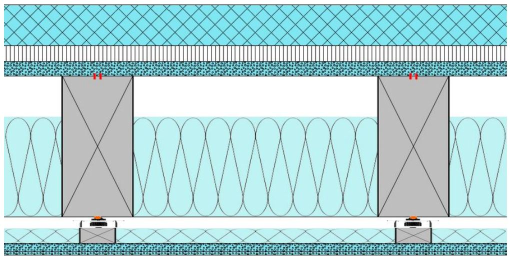
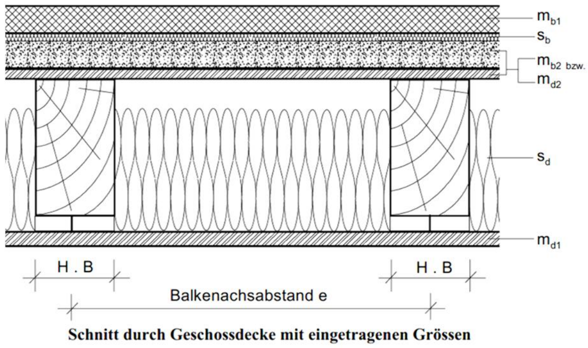
Sample Catalog	Sample Kühn & Blickle
	

Figure 10: Assignment of mass according definition in formula

2.10 Integration Auralisation

Figure 11: Visualization of the auralisation inside the database.

2.11 Future use of the database with BIM

The concept of www.lignumdata.com is an example of how information on products and components could be digitally provided for broad use.

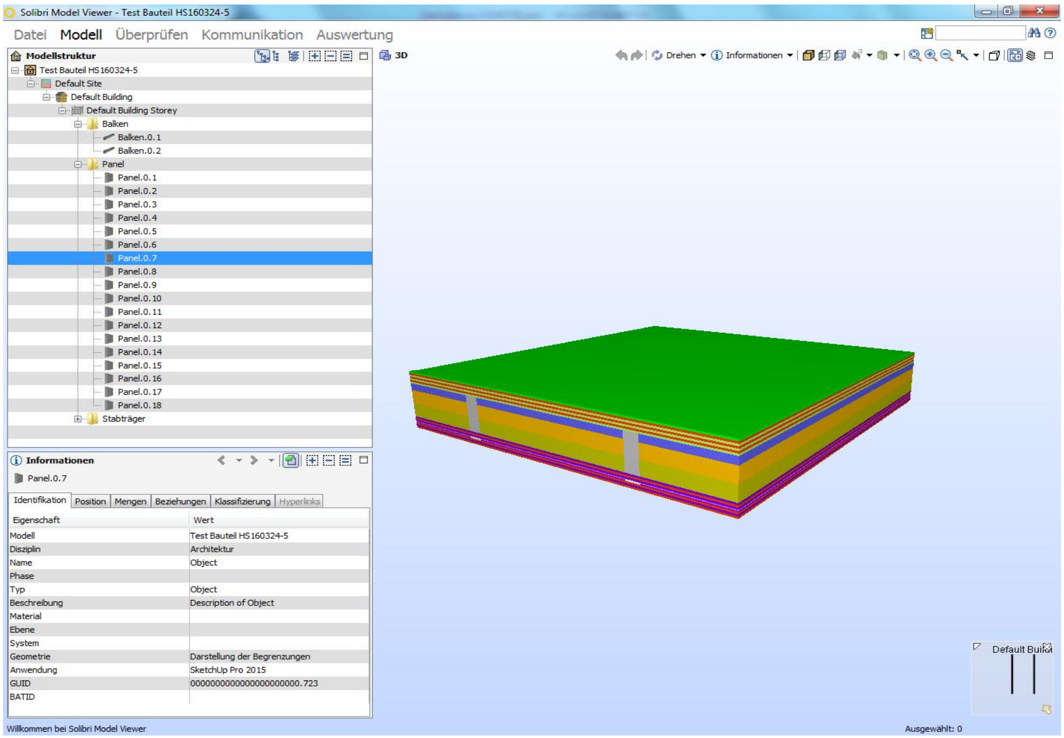


Figure 12: Component as ifc file in BIM application

2.11.1 Major challenges in climate change and resource safety

The ambitious goals for the reduction of greenhouse gas, energy consumption and resource efficiency cannot be achieved without taking into account the construction sector. Fortunately there are still great potentials for optimization in the construction industry - the construction industry is just at the beginning of the digital transformation.

2.11.2 Linking test results direct to practice – finally!

Test institutes generate a large amount of valuable information. How can all this information be applied in practice in a simple and efficient manner?

The information can be collected in online databases, trough filters the right solutions can be found by engineers and architects. Via files available in the international readable ifc.-format, the found information can be imported into the CAD-design program without additional effort. Only thanks all to those information, different building variants can now be evaluated, compared and optimized in earlier stages of design - a whole new planning quality with advantages for all involved in the project!

2.11.3 IFC format as link to SEA wood?

The product information in the ifc files could be extended by values needed in SEA.

3 Introduction Auralization Conception

Within the Silent Timber Build Project, the Fraunhofer Institute of Building Physics IBP was responsible for the project subtask ”Auralisation”. Aim was to auralise the impact sound insulation from the Lignum database “European Timber Sound Insulation Atlas”. The database with the auralisation will be made available to the public via a website (www.lignumdata.ch).

3.1 Basic Elements of the Auralisation

In reality, the impact sound transmission is generated in the source room, for example by walking, and is distributed by the floor into the building. The signal propagates through the floor and walls (flanking transmission) and is radiated into the receiving room as airborne sound. Finally, the sound reaches directly or via reflections the ear of the listener. In virtual reality, the sound paths from the sound source to detection by the listener are described by transfer functions. The influence of the receiving room is described by the room impulse response. Furthermore, a suitable sound source signal is required, which is first filtered by the transfer functions of the floor and then folded with the room impulse response, see figure 13. The resulting signal is presented via loudspeakers or headphones.

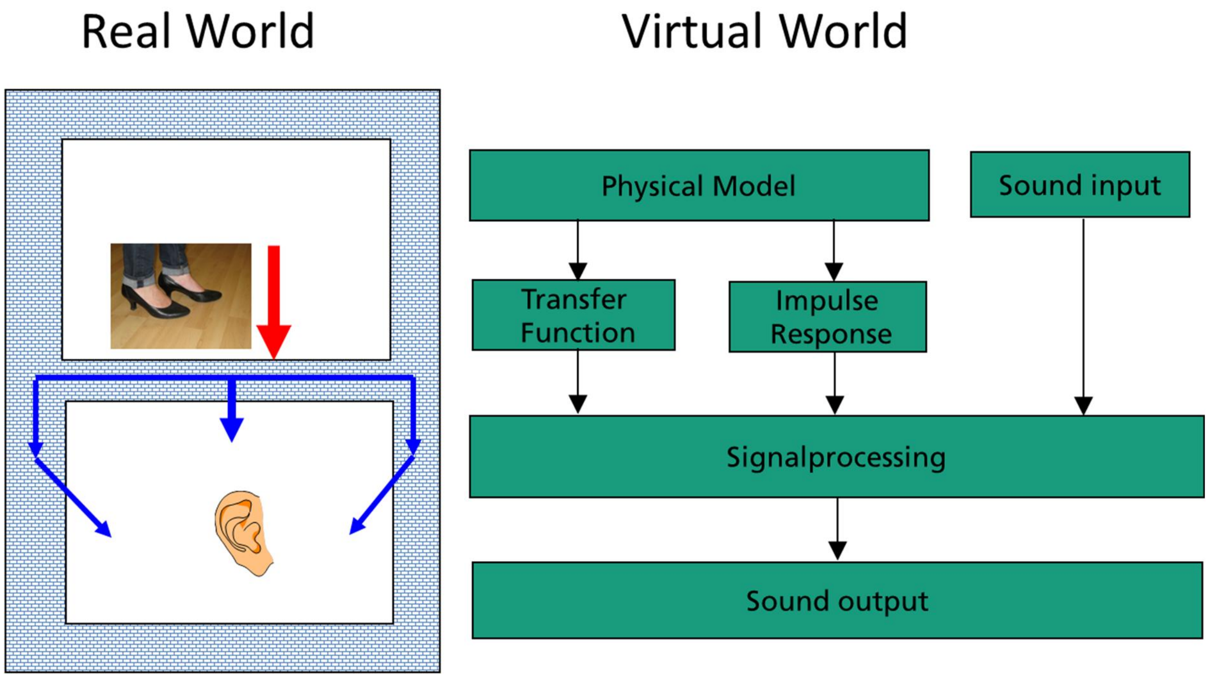


Figure 13: Schematic comparison of the structure-borne sound propagation in the real and virtual world.

3.2 Requirements to be met by the development environment

Since the devices and operating systems applied by the user are not known, the selected development environment must ensure that the final program runs on as many systems as possible. In addition, it is required that the sound files can be edited and played back. Finally, the auralisation is to run fast, virtually in real time. Due to the system independence, JAVA was selected as development environment. During the initial development period, the JAVAFX data library was published, which contained the necessary signal processing functions that were used after testing.

3.3 Definition of the interface to the database

As a first step an interface to the database was defined. The database includes the impact sound levels as one-third-octave-band levels, octave-band levels or single number values. Accordingly, a named parameter “auralisation” was defined, which is followed by a string, the tokens of which are separated by blanks. The first token is one of the letters E, O or T, which describes the type of the subsequent data.

3.3.1 Token E

The token E indicates a single number value, followed by an integer value for the weighted normalized impact sound pressure level.

3.3.2 Token O or T

The token O indicates octave band values, token T indicates third-octave band values. The first integer value marks the rounded centre frequency of the lowest data frequency band. This is followed by the normalized impact sound pressure levels in ascending third octave or octave band frequencies. Here, the third value is the impact sound pressure level of the frequency band specified in the second token, while all other values are impact sound pressure levels of the ascending third octave centre frequencies or octave centre frequencies. As missing value “-9” was defined. By use of a small test program it was shown that the interface worked and provided all required data.

3.4 Generation of the sound source signals

In the test facility for floors (P8) of the Fraunhofer IBP various floors were installed and measured. In the receiver room sound recordings of different excitation sources were performed. The receiving room with a volume of 45 m³ (room dimensions 4.80 m x3.80 m x 2.48 m) was conditioned to a reverberation time of about 0.5 s. Thus, these recordings contain a common transfer function from floor to microphone in a room, equipped with standard furnishing. This represents a pragmatic approach to take into account the room conditions, which can vary widely. This approach also corresponds to the initial intension of the auralisation, which enables a comparison of different floors under “standard” conditions by simple and quick signal processing. The recordings were converted to a virtual floor construction, the frequency spectrum of which corresponds to the reference curve according to DIN EN ISO 717-2 [5]. This was done by taking into account the third octave band frequency spectrum of the measured floor and filtering the signal by the difference of the third octave band frequency spectrum to the reference curve spectrum. Thus, this signal still includes the time component of the excitation signal, as for example the sequence of hammer drops of the standardized tapping machine or the steps of the walkers, the interaction between the physical source and the floor, the impact sound transmission within the floor, the airborne sound radiation into the receiving room under real conditions and the transfer function of the airborne sound to the microphone position at a height of 1.77 m (standing person) in the receiving room. For some other available recordings of floors, the signal especially at high frequencies was so weak that only a small signal-to-noise ratio to the background noise existed. As a result, the background noise dominated in the signal after increasing the levels up to the reference curve. Therefore, finally the existing signal of a floor showing the smallest deviations in the frequency response from the shifted reference curve was chosen for generating the signals of the virtual floor construction (floor 2).

As sources a standard tapping machine, a ball, a male walker and chair pulling across the floor were used. For the ball signal the Japanese rubber ball was used, as described in DIN EN ISO 10140-5 [6]. The drop height was 1 m. In the receiving room the impulsive signal levels were so high that the auralisation resulted in the overmodulation of the signal. Therefore, the level of the ball was reduced in the auralisation by 10 dB, allowing this signal also to be used.

During the auralisation, the recordings were increased respectively reduced in steps of 20 dB and saved in different files, which were accessed by the programming as required. This was done to remove restrictions in the signal dynamic range, as described in [chapter 3.6].

3.5 Testing of JAVAFX

Right after starting programming, Oracle published JavaFX [7]. This program library contains several objects and methods that are interesting for audio editing. The object "media player" contains both the method "setVolume" and an equalizer with freely definable frequency bands.

3.6 setVolume

According to the documentation of Oracle JavaFX, with setVolume a value between 1 and 0 is set. Thus the following questions arose: How are the dB values converted into the linear scale? Is the dB scale independent of the volume set at the computer? A small test program was created and the audio output was measured at different computers.

$$lin = 10^{(dB-dBNorm)/20} \qquad [5]$$

It became evident that with the dB values can be converted into linear values (lin). The value "dBNorm" ensures that the permitted range of values of the method setVolume is met. At the same time, it became apparent that the difference between two levels remains constant, independently of the volume set at the computer. However, the tests also made obvious that the dynamic range of the method setVolume amounts to only 30 dB. With larger level differences, the output of those frequencies is turned to mute. Therefore, with a larger dynamic range of the signal spectrum, a change of the playback sound for the lower frequency ranges occurs. This is shown in Figure 14 for the test measurement of impact sound signals with different levels.

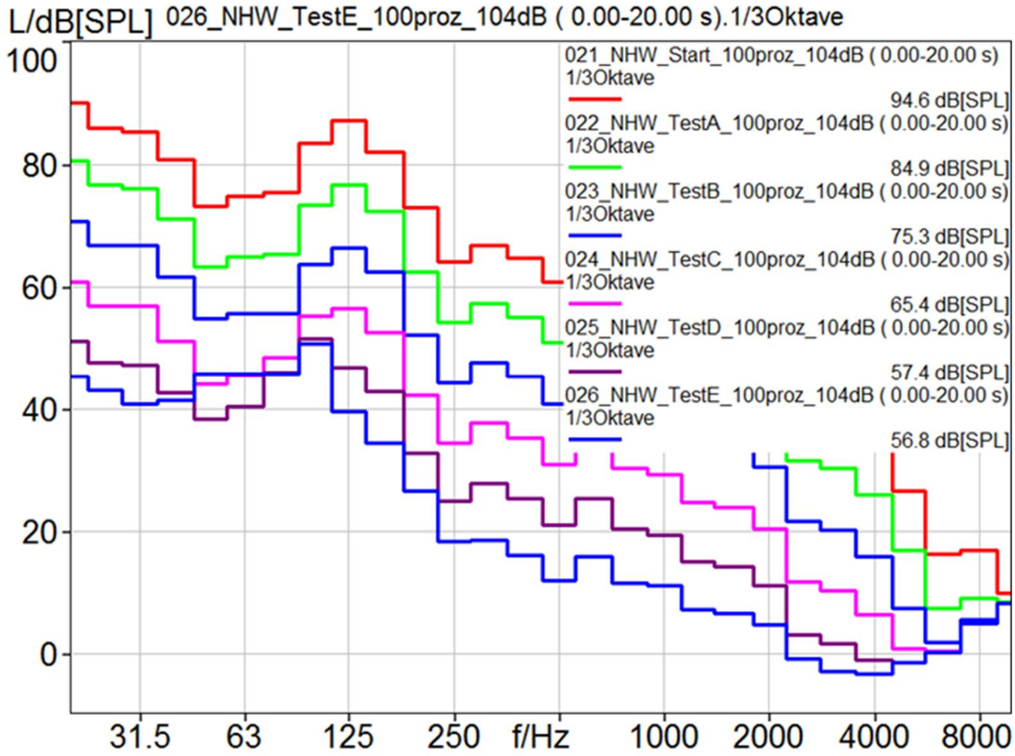


Figure 14: Measurement of the output signal

Measurement of the output signal “standardized tapping machine“ at the headphone jack for different levels in steps of 10 dB. Up to a noise reduction of 30 dB the individual curves are shifted in parallel. With larger level differences, reduction of the dynamic range and other artefacts occur.]

To avoid these restrictions, several sound signals of the same sound source were created, as mentioned in section 5, having a level difference of 20 dB. By choosing the relevant sound signal and the function setVolume it became possible to increase the output dynamic range up to approx. 60 dB, which allowed to display the dynamic range required for the impact sound auralisation by the program (lowest noise level in “normal” environment ca. 20 – 30 dB, highest impact sound pressure level of a simple ceiling ca. 90 dB). By implementing the above mentioned methods, the restrictions of the dynamic range in the program design were overcome and the use of setVolume became suitable for this auralisation.

3.7 Equalizer

The equalizer is a collection of Equalizer Bands defined by center Frequency, bandwidth and gain. Center Frequency and bandwidth can be freely defined. The number of frequency bands is not limited. The value of gain is limited to the range of + 12 dB to-24 dB. For the use of this function, another test program was created and the sound output was measured at different computers. The set values of the levels, frequencies and bandwidths were confirmed by the test program and the remeasurement of auralised signals. Thus, the equalizer is also suitable for the auralisation.

3.8 Result of JavaFX test

With JavaFX, Oracle provides a library that can be used for auralisation. Compared to a signal processing Java program, JavaFX offers considerably higher speed, as it accesses hardware resources. These low-level direct accesses are not allowed for Java programs. Attempts to determine the time between the mouse click and the system message indicating the start of the auralisation failed due to the insufficient system response times (response time less than 35 ms). In comparison, the system response time of an own program for signal processing is about one second. This is why we decided to choose the JavaFX library for the auralisation.

3.9 Auralisation program

3.9.1 Basic concept

Since the source signals had been conditioned such that they corresponded to the frequency response of the reference curve, and since the signal, included already the transmission function of a "typical living room", only the frequency-band-dependent differences of the impact sound levels of the floors from the reference curve had to be incooperated in the auralisation. Due to the limits of the dynamic range described in section 6.2, an additional level selection and adaption is carried out.

3.9.2 Realisation

As soon as the interface data described in chapter 4 are received from the database, an equalizer object is initialized. In the case of single number values or octave band values the equalizer comprises the octave center frequencies from 31.5 to 16000 Hz. For third-octave band values, the third-octave center frequencies from 31.5 to 16000 Hz are initialized. In addition to the determination of the band center frequencies and band widths, the initialization includes the setting of the gain to 0 dB and the specification of its valid value range.

The next step is to calculate the control variables of the equalizer. For this, the impact sound pressure level of the start frequency is determined for frequency-band-dependent data between the 31.5 Hz band center frequency and the start band center frequency of the transferred data set. Here, all third octave and octave bands below the start frequency of the data set are linearly extrapolated, i.e., for example for a dataset with a value of 63 dB at 50 Hz start frequency, the third octave values for 40 and 31.5 Hz are also set to 63 dB. Above the highest band center frequency (usually 5 kHz) the reference curve is extrapolated with -3dB/third octave, or with -9dB/octave, respectively. These extensions of the frequency range correspond to the extrapolation of the reference curve for low and high frequencies. In the case that values are missing in the data set – this case should never occur in the database – the missing value will be interpolated between the existing side values of the gap. For the extended raw data thus obtained, the impact sound pressure level difference at the band center frequency of 500 Hz is determined for the stored reference curve for third octave and octave bands. As raw control variables, the differences between the extended raw data and the corresponding reference curves reduced by the impact sound pressure level difference are determined in frequency bands. The setting of the equalizer for third octave and octave band data complies with the respective impact sound pressure level difference of the individual frequency bands. For the auralisation by single number values, however, the start signal adapted to the course of the validation curve is adjusted only with regard to the level, the frequency response will not be changed since there do not exist such information when utilising single number values for the auralisation.

As the next step it is checked whether the raw control variables are within the dynamic limits of the equalizer bands. Three cases can be distinguished:

3.9.3 All raw control variables are within the dynamic range

In this case the equalizer can be set and the control variables correspond to the raw control variables.

3.9.4 Not all of the raw control variables are within the dynamic range, yet the difference of the extreme values is smaller or is equal to the dynamic range of the equalizer.

If the dynamic range is exceeded, the setting level is amplified by the difference between the maximum exceedance and the upper dynamic limit whereas the raw control variables are reduced by the same value. If the dynamic range is deceeded, the setting level is reduced by the difference between the lowest possible value and the lower dynamic limit whereas the raw control variables are amplified accordingly. Hence, the control variables correspond to the corrected raw control variables.

3.9.5 Not all of the raw control variables are within the dynamic range, yet the difference of the extreme values is larger than the dynamic range of the equalizer.

In this case a lossless correction of the data is not possible. Here, the “loud” frequency bands of the impact sound pressure levels are reproduced correctly, whereas the “low” frequency bands are amplified such that they are still within the dynamic range of the equalizer. For this, the difference between the maximum of the raw control variables and the upper dynamic limit is determined. This difference may also be negative. The setting level is amplified accordingly, whereas the raw control variables are reduced. All raw control variables below the minimum dynamic range are set to the value of the minimum dynamic range.

3.9.6 Playback of the auralisation

Before starting a new auralisation playback, any other still running playback will be stopped and the required objects will be released. After selecting a noise signal, the appropriate noise file is selected, regarding the setting level. For this noise, a suitable equalizer is generated according to the procedure above and the play back level is determined. Then the play back starts.

As mentioned, the initialization of the objects, including the calculations and the play back start is so fast that it cannot be measured by the computer clock. Therefore, it was not considered to retain objects after being required for the performance. The basic programming process of the auralisation is presented in Figure 15.

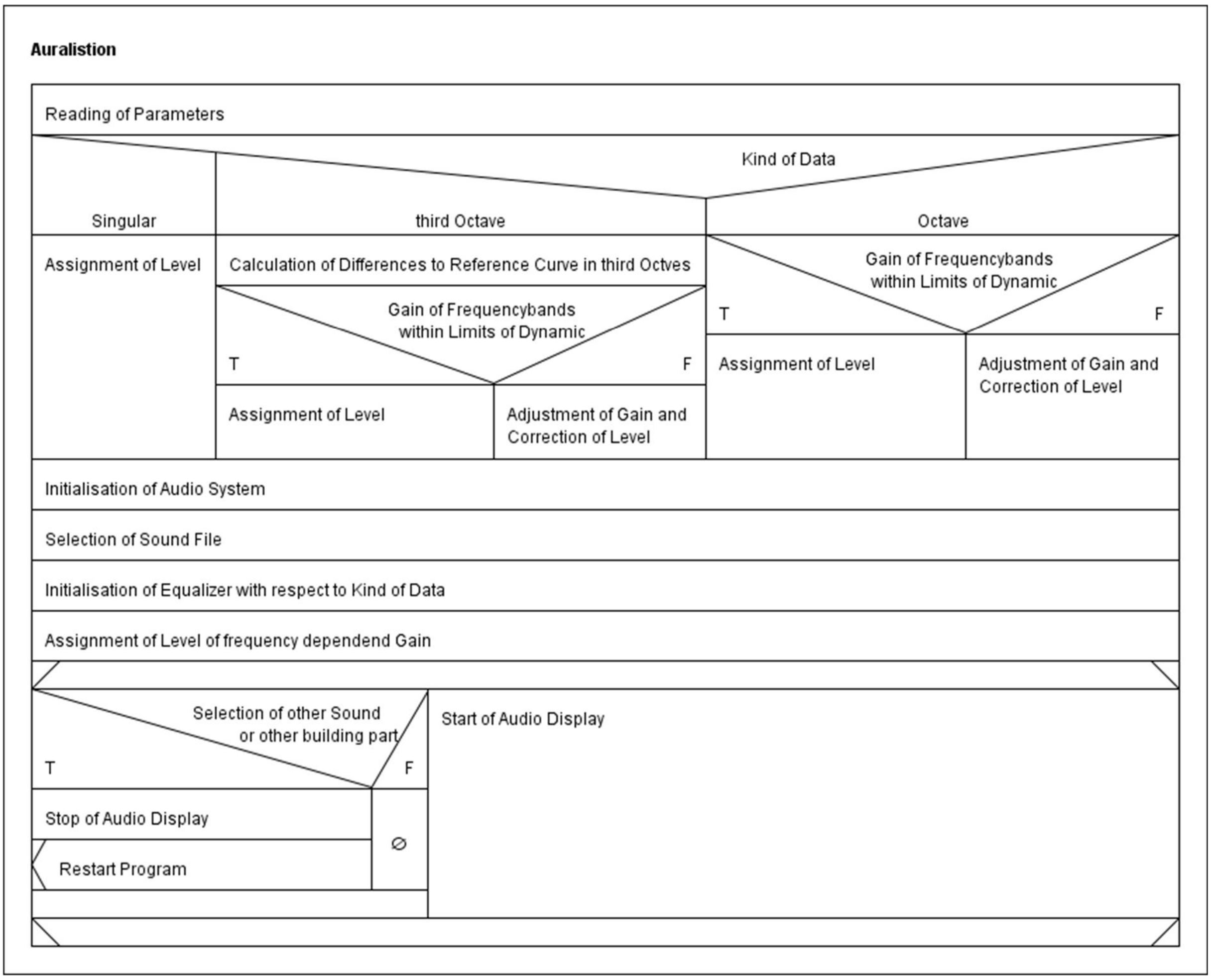


Figure 15: Nassi-Sneiderman-diagram of the auralisation process

The fast performance of the auralisation enables to switch back and forth between auralizations of different floor constructions and thus allows for an acoustic A - B comparison between these floors, so that the user can get a comparative impression of the floor constructions.

3.10 Validation

The auralisation was validated on the basis of 10 test data sets including both real floors and typical test data. For the measurement-based validation, the auralised signals were transferred from the output of the sound card of different computers directly to a measuring system, evaluating the impact sound pressure levels and the spectra. The validation measurements were not carried out by the software developer. Pending the availability of the results, the persons carrying out the measurements did not know which parameter set was currently to be measured. It became evident that within the tolerance of 1 dB the measured values and the control variables corresponded. The used test data are presented in Table 3, the comparison between the parameters used in the auralisation and the measurement data are shown in Figure 16.

Table 3: Overview of the applied test data

Floor	parameter set	description
floor1	T 50 68 71 74 72 74 74 70 72 68 68 66 64 58 53 48 45 42 43 39 30 19	floor1
floor2	T 50 67 64 68 67 63 64 61 64 59 57 57 54 55 55 53 51 51 44 32 22 15	floor2
floor3	T 50 67 70 66 58 59 60 59 55 52 50 45 40 37 34 31 28 28 28 24 15 11	floor3
floor4	T 50 60 59 60 58 57 62 61 59 56 55 56 53 50 47 43 41 36 36 27 19 10	floor4
floor5	T 50 58 54 52 50 44 48 49 49 43 39 37 39 39 37 40 42 39 33 29 18 6	floor5
floor6	E 60	reference curve in single values
floor7	O 63 67 67 67 65 61 53 44	reference curve in octaves
floor8	T 50 62 62 62 62 62 62 62 62 62 61 60 59 58 57 54 51 48 45 42	reference curve in third octaves
floor9	E 58	floor2 as single value
floor10	0 63 71 70 66 61 59 54 33	floor2 in octaves

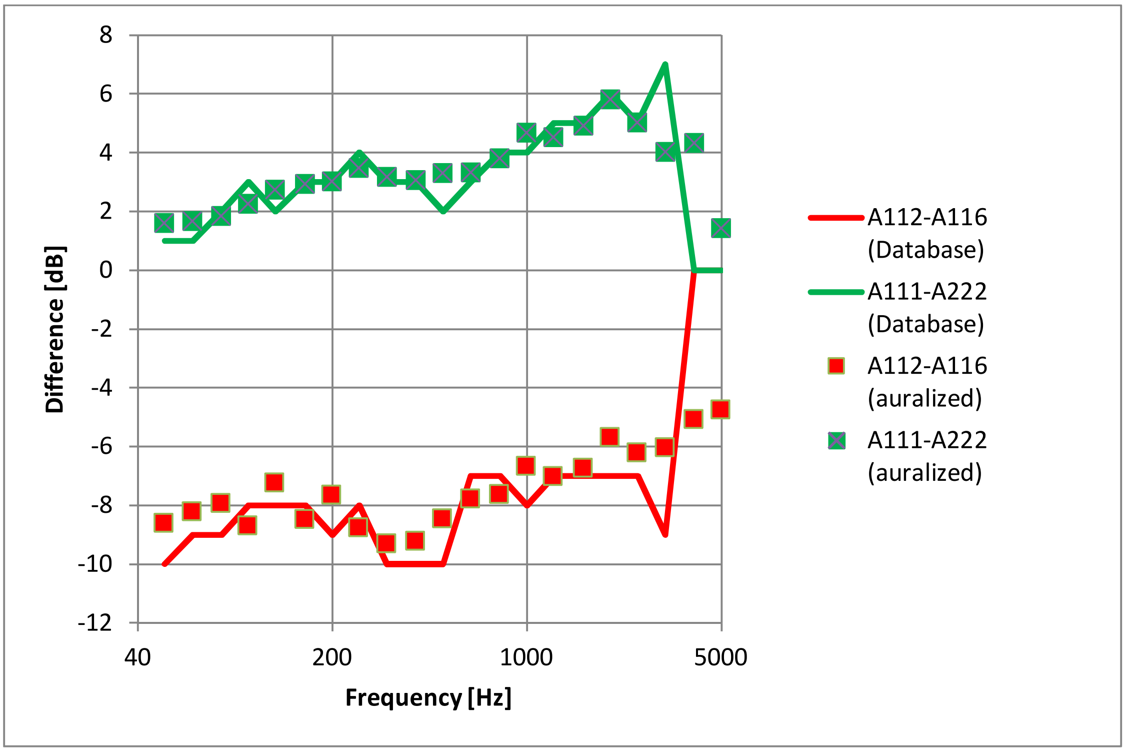


Figure 16: **Comparison of measured (line) with auralised (sqares) difference to the reference curve. The deviation between red or green line (original spectrum) and auralised spectrum (red or green dots) are mostly within 1 dB, except at high frequencies with low sound pressure levels.**

In addition to the comparability of the auralisation spectra, the auralisation was also validated psychoacoustically. The psychoacoustical hearing test carried out in this context is described in detail in [Chapter 3.9.] It can be stated that the psychoacoustical validation has also confirmed the validity of the auralisation.

3.11 Volume calibration

Within the frame of the psychoacoustical validation it was also examined how various methods that are not measurement-based, which is not possible with the intended application of the auralisation via the Internet, can be applied in order to set the volume of the terminal device by the user. These examinations are described in detail in [Chapter 3.9]. It was found that a calibrated speech signal set manually to a normal speech volume by the user at the terminal device is the most economic method. Therefore, this volume setting method was realized in the auralisation.

3.12 Connection to the database

To ensure that the auralisation tool can also be connected to the web frontend of the database, two connection types were tested by designing a website for each connection which, by mouse click, provides the auralisation tool with data and starts it.

3.13 Statical connection to the website

For this type, the auralisation tool is permanently implemented in the website, thus offering the advantage that data and the playback buttons are arranged side by side. However, the disadvantage is that for every change of the building component the auralisation tool is changed as well, thus leading to waiting times and data volumes to be transferred. An example for this type is the website ”JavaAuralisation.html“, which includes the auralisation of all 10 floors presented in Table 1.

3.14 Dynamical display of the tool in a separate window

With this type, the auralisation tool starts in a separate window and is provided with data prior to the website. Here, the advantage is that the tool has to be started only once, thus ensuring shorter waiting times and less data volume transfer. Via a cookie, the description and data of several building components can be managed thus allowing an A-B-comparison of different constructions. The disadvantage here is that the auralisation tool is not automatically linked to the use of the database but is only possible on another website. As an example, this type was realized by the website “JavaAuralisationLignum.html” where different data sets can be entered manually to ensure the A-B-comparison of these different auralised data sets.

Which of the presented types or whether a third type will be realized for the connection of the auralisation to the database by Lignum is not part of the described task, but will be implemented by Lignum and its programmers, respectively. The use of the two described website types is presented in [Annex 1].

3.15 Conclusion

An auralisation tool for the connection of the Lignum database of floor constructions (database “European Timber Sound Insulation Atlas”) was realized, using exclusively Internet technologies. With the exception of the website setup, the auralisation virtually works in real time, thus allowing to perform A-B-comparisons. The auralisation was validated by measurements and psychoacoustically. Thus, for the first time a validated real-time auralisation of impact noise becomes Internet-compatible and is made available via the Internet for a large number of users.

Acknowledgement
The author wishes to thank Moritz Späh and Bernd Kaltbeitzel for performing the measurements, and Soheib Akbar for the support in implementing the auralisation in a test website.

4 Auralization

4.1 Listening Test

The listening test conducted within the project module "European Sound Insulation Atlas" was used to validate the auralisation tool developed in the same project module. The auralisation tool is used to improve the accessibility to the sound insulation in wooden buildings for a broad public, but also as an instrument for predicting acoustic behavior between different rooms, floors etc., by consultants, industry and product developers in practice.

The Auralization tool uses the data from the EATSI atlas to give acousticians and non-acousticians an audible impression of different sound insulation effects in European wooden buildings. By the use of listening tests, we get an understanding of which perception and reaction particular acoustic environmental conditions have (in certain target groups). The listening test presented below was used to evaluate the extent and differentiation of the hearing impressions that can be generated by the developed auralisation tool.

4.2 Noise rating

4.2.1 Introduction

For an auralisation tool designed to support and assist the user at his/her computer at home, a close correlation between the auditory impression of the tool and the auditory impression in a building is very important. The listening test thus helps to qualify both the auralisation algorithm and the applicability for the user at home.

In order to assess the quality and usefulness of auralized sounds for application to the product presentation and as a decision aid for customers, the sound impression of auralized sounds relating to specific floor constructions was compared to the sound impressions related to sounds of the same floor constructions recorded in buildings. If the sound impression of auralized and recorded sounds does not differ significantly, auralisation can be qualified by this result as useful method. If, however, the results differ considerably, the auralisation needs to be further improved.

Likewise, it is also essential that the auditory impression should clearly reflect the different quality levels of the various floor constructions, i.e., a very good floor also performs well with regard to the auditory impression, and the auralisation tool can thus be an adequate purchase or decision aid for the customer.

Furthermore, the question arises about the usability of the tool in different application contexts, for example as an online tool for individual use at home. It must be noted that the transmission path for sound reproduction varies in different contexts and the playback level cannot be controlled. For this reason, two methods for volume calibration, which use_the human sense of hearing and which are independent of the situation and technical equipment, were tested in the listening test.

4.2.1.1 Hypotheses

The following hypotheses are examined in the listening test:

1. Are there any qualitative or quantitative differences (perceptible by humans) between the original recordings and the auralized sounds?
2. Are quality differences between the various floor constructions perceptible in the auralized sounds?
3. Are quality differences between the various floor constructions perceptible in the original recordings?
4. Are there any differences in the perception of the sounds auralized on the basis of octave, third octave and single number values?
5. Which method is suited best for the loudness calibration at the customer's home? What about the accuracy and costs of the two methods (cost-benefit analysis)?

For the examination of the listed hypotheses, the method was as follows. Original noise from different measuring excitements and floor constructions from recordings in buildings, as well as auralized sounds of the same excitations and floor constructions were presented via headphones and rated with regard to standardized loudness and annoyance scales [1; 2]. In addition, further auralized sounds (without the corresponding original recording) were presented for evaluation. The goal in this part was to compare auralizations, which were created on the basis of different data availability, with each other and with original recordings. Subsequent to the noise assessment, the methods for volume calibration were tested in a second test part.

4.2.2 Method

4.2.2.1 Subjects

The hearing tests were attended by 11 male (52.4%) and 10 female (47.6%) test persons aged between 19 and 29 (average age = 27.9 years). Most of the test persons were students. All subjects attended both the first part (noise rating), and the second part of the test (evaluation of the calibration method). The test persons were paid for participation.

4.2.2.2 Materials and sounds

The listening test was carried out in the test room for integral impact research, the High Performance Indoor Environmental Laboratory (HiPIE-Lab) of the Fraunhofer Institute for Building Physics (IBP) in Stuttgart (see Figure 17).

Figure 17: Test laboratory for integral impact research, (HiPIE-Lab) of the Fraunhofer IBP.

Figure 18 shows the test setup consisting of 2 x 2 identical workplaces. There were two workplaces set up for the first part of the test (noise rating), and two workplaces set up for the second test part (loudness calibration). This was necessary because different technology was used for the two test parts. Thus, it was possible to avoid that the technology applied in one test part interferes or distracts the performance of the second test part (for example by displays or fan noise). Two persons were tested at a time in one session.

Figure 18: Experimental setup in the HiPIE laboratory. Two identical experimental workplaces were set up for each experimental part. Two people were tested in parallel.

In the listening test, the subjects rated both auralized sounds and original recordings with regard to loudness and annoyance. The rating was carried out by help of the Sound Quality Representation and Evaluation Studio (SQuare) from Head Acoustics. Each test station is equipped with its own equalizer (PEQ V: Programmable Digital Equalizer), a headphone (SENNHEISER HD 280 pro) and a tablet (Lenovo ThinkPad) (Figure 19). Following the noise playback via headphones, the subjects evaluated the last heard noise on predetermined scales via Tablet PC.

The individual test stations are connected to a master computer (WLAN), the experiment is controlled by the examiner (Figure 20).

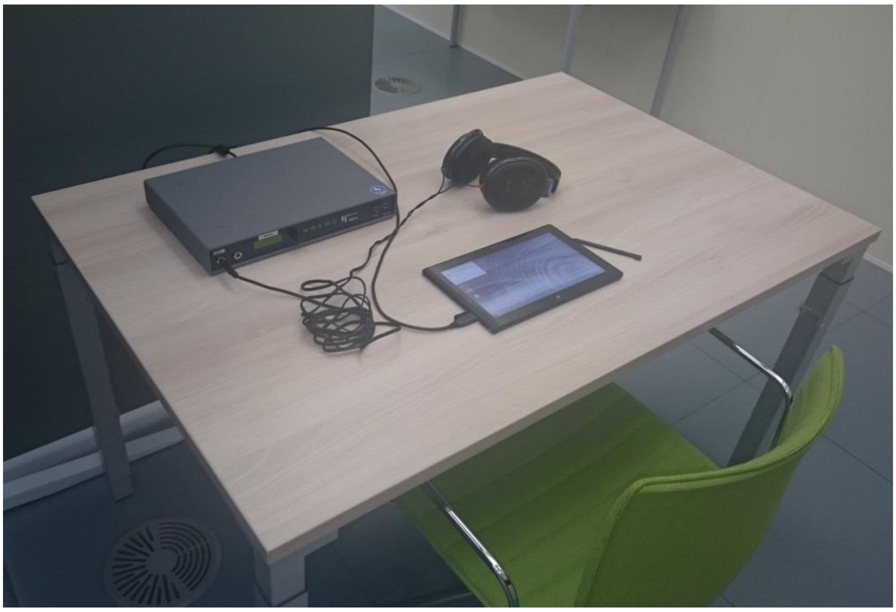


Figure 19: Setup at a test site for test part 1 (noise assessment). The Sound Quality Representation and Evaluation Studio (SQuare) from Head Acoustics was used in the listening test.

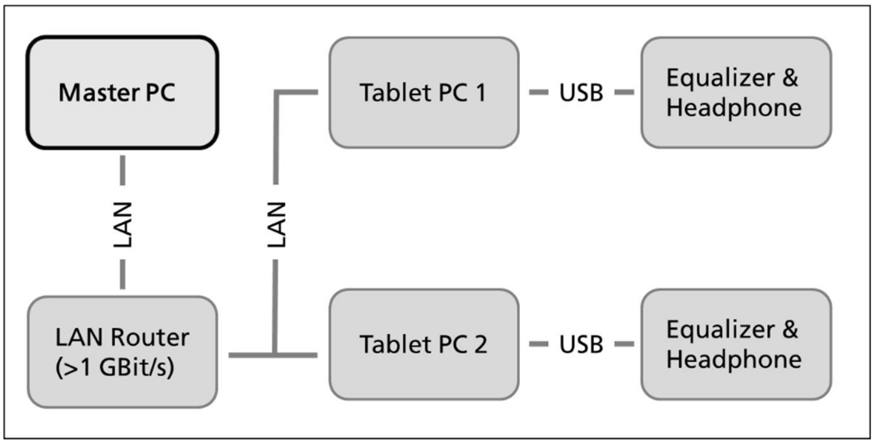


Figure 20: Test setup with two test stations. The sound is reproduced via headphones and equalizer at each test site. The noise is assessed using a tablet. The test control runs via a master PC, all test stations are connected to (WLAN).

The sounds to be rated are available in HDF format and are played on the tablets at the individual test stations via the master PC. Since each test place is provided with an own amplifier, the sounds were automatically played true to their original sound pressure, and each test person could do the test individually in his/her own pace.

The test persons rated 60 sounds regarding loudness and annoyance. For 5 floors there were four excitations each with one auralized sound and one original recording (5 x 4 x 2 = 40 sounds). For several additionally auralized sounds (floor 6-10) there were no original recordings available, but also 4 excitations (5 x 4 = 20; in total 40 + 20 = 60 sounds).

Since each of these noises should be evaluated in terms of loudness and annoyance, a total of 120 trials of playback and evaluation were completed by the test persons.
The sound reproduction could be controlled individually. Each sound had to be listened to at least once before rating. The subjects first rated the annoyance, then the loudness of all sounds.

The sounds were rated according to an 11-level annoyance scale (not annoying – extremely annoying) 0 and a 6-level loudness scale (not heard – too loud) [2] which were predefined by the display on the Tablet PC.

Table 4: The meanings and descriptions (as well as the impact sound of the original floor) of the floor notations used in the following are shown in the table.

name	description	Impact sound pressure level of original floor Ln,w+CI,50-2500
floor 1	floor1	66,9 dB
floor 2	floor2	59,8 dB
floor 3	floor3	58,4 dB *
floor 4	floor4	55,0 dB
floor 5	floor5	46,7 dB
floor 6	reference curve in single values	
floor 7	reference curve in octaves	
floor 8	reference curve in third octaves	
floor 9	floor2 as single values	
floor 10	floor 2 in octaves	

*Special value: high $C_{I,50\text{-}2500}$ (= 8 dB) due to suspended floor, resulting in a poorer quality at lower frequencies.

4.2.2.3 Procedure

At the beginning of the sound rating, the test persons passed a training trial with two sound ratings to get acquainted with the task. In addition, a very quiet and a very loud sound of the listening test were played in the trial to provide a reference range for the subsequent rating. Then the test persons rated the annoyance of 60 sounds, and the loudness of 60 sounds. Each sound had to be played back at least once and rated afterwards. The 60 sounds were presented in randomized order. After the sound rating, test sites were changed and the second part of the test (loudness calibration) started. The test (all test parts) took about 1 hour in total.

4.2.2.4 Design

For the comparison between auralized sounds and the recorded original sounds a 2 (type of noise: auralized, recorded) x 5 (type of floor: floor 1, floor 2, floor 3, floor 4, floor 5) x 4 (excitation: tapping machine, rubber ball, male walker, chair pulling) – within-subjects design with repeated measurement was used. The additionally auralized floors 5-10, for which no original recording was available, were tested accordingly in a 5 (type of floor: floor 6, floor 7, floor 8, floor 9, floor 10) x 4 (excitation: tapping machine, rubber ball, male walker, chair pulling) – within-subjects design with repeated measurement. As dependent variables, the subjectively perceived loudness (7 level scale) [2]and annoyance (11 level scale) 0 were measured.

4.2.3 Results

4.2.3.1 Comparison between auralization and measurement

Subject of the examination was the subjectively perceived loudness of auralized and recorded sounds. Figure 21 presents a comparative overview of the averaged loudness ratings of all test persons for auralization and recording. In the loudness rating, eight of the twenty tested excitations showed significant differences between auralization and recording. These differences were highlighted in red in the labeling of the x-axis (Figure 21). The results of the significance test can be found in the appendix of this report (Appendix 1). Floor 2 did not show any significant differences compared to the other floors. Since the calculation of the auralization was based on floor 2, there is probably a larger similarity between recorded and auralized signals, which is also reflected in the subjective ratings. The most frequently occurring differences between auralization and recording were detected with the rubber ball which can be attributed to the complexity of the signal (see discussion).

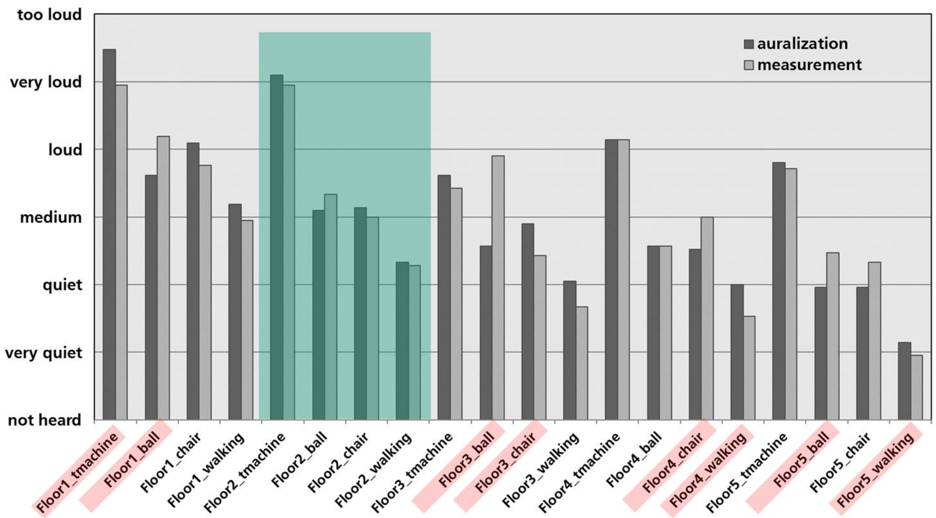


Figure 21: The diagram shows the results of the loudness rating for auralized and recorded (measurement) sounds of the floor constructions 1-5 for all four excitation types. The green highlighter marks the results of floor 2. These results are interesting because all calculations of auralized sounds are

based on floor 2. The red markings show significant loudness rating differences between auralization and recording.

When comparing the levels of auralized and recorded sounds, for many of the sounds subjectively perceived as significantly different regarding their loudness, an objectively existing level difference becomes apparent (see Figure 22). The perceived loudness levels highly correlate ($r(38) = 0.956$, $p < .001$) with the real sound pressure levels (Figure 22). The perceived loudness differences between auralization and recording thus can partly be attributed to the actually existing loudness differences that are due to the auralization procedure.

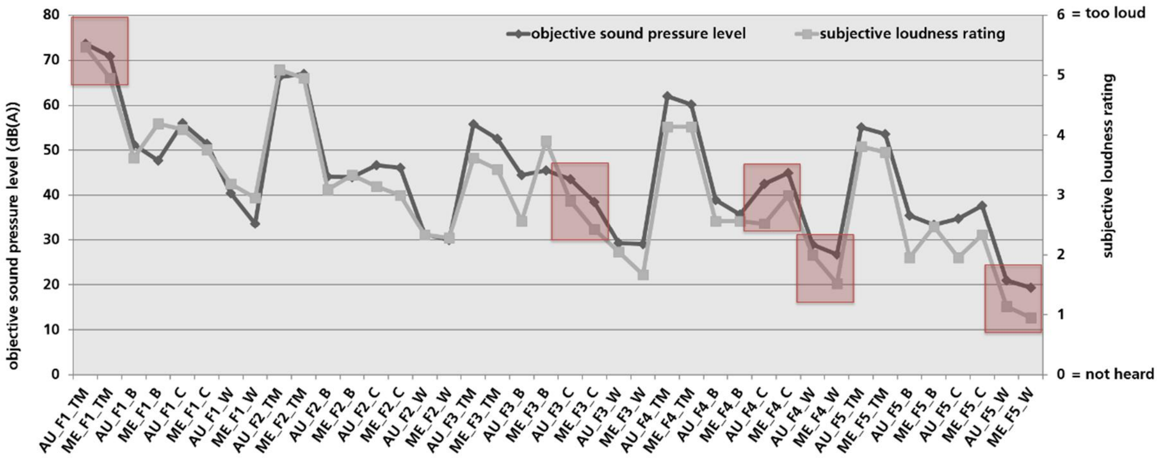


Figure 22: In the diagram for each signal (auralized and recorded) of floor 1-5 the actual level is displayed in dB(A) (y-axis left) and the subjectively perceived loudness (y-axis right). Related auralized and recorded sounds are displayed next to each other (x-axis). The following abbreviations are used: AU = auralization, ME = measurement (recording), F1 – F5 = floor1 – floor 5, TM = tapping machine, B = ball, C = chair pulling, W = male walker. For the red marked signal pairs, there was a significant difference between the loudness of the auralized sounds and the loudness of the recorded sounds.

Besides the loudness, also the subjectively perceived annoyance of the auralized and recorded sounds was measured in the listening test. Figure 23 shows a comparative overview of the results obtained from the subjective annoyance rating for all signals for the auralized and the recorded sounds. Only 4 out of 20 signal pairs of the annoyance rating showed significant differences between auralization and measurement. These differences were highlighted in red in the diagram. The results of the significance tests can be found in the appendix of this report (Appendix 2). As with the loudness rating, the 4 excitations of floor 2 did not show any significant differences between auralisation and measurement. Since all auralizations were based on the recordings of floor 2, it can be assumed that the auralizations here are particularly coherent with the original recordings. The ball, again, performed critically which might be attributed on the one hand to difficulties in the auralization, and on the other hand to the difficulties in the rating of short impulsive signals.

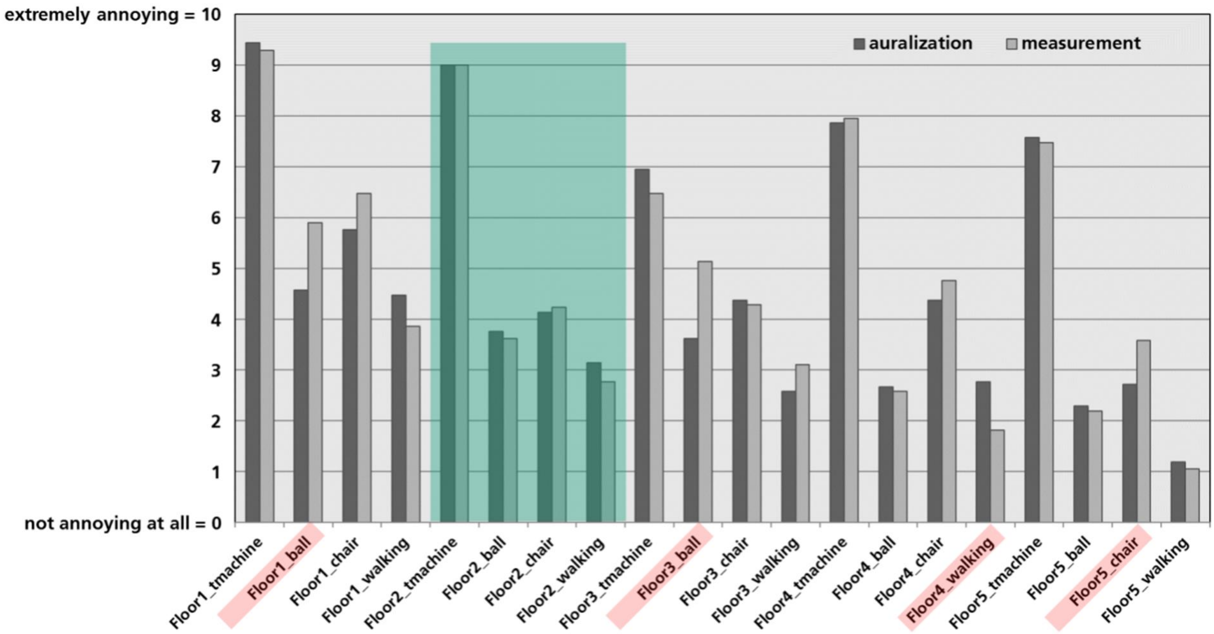


Figure 23: The diagram shows the results of the annoyance rating for auralized and recorded (measurement) sounds of the floor constructions 1-5 for all four excitation types. The green highlighter marks the results of floor 2. These results are interesting because all calculations of the auralized sounds are based on floor 2. The red markings show significant differences in the annoyance ratings between auralized and recorded sounds.

4.2.3.2 Comparison of different floor constructions

Besides the comparison between auralized and recorded sounds, it is also relevant to compare qualitatively different floor constructions. Likewise, this comparison is based on the loudness and annoyance ratings performed by the test persons. The comparative interference-statistical calculations were carried out both for the recorded and for the auralized sounds.

Table 5: Impact sound level of the compared floor constructions 1-5.

Floor	$L_{n,w}+C_{I,50\text{-}5000}$
Floor 1	66.9 dB
Floor 2	59.8 dB
Floor 3	58.4 dB*
Floor 4	55.0 dB
Floor 5	46.7 dB

* Note: high value of $C_{I,50\text{-}5000}$ (=8 dB) due to suspended ceiling, leading to higher levels at low frequencies

Distinct existing differences between the floor constructions regarding the impact sound pressure level are reflected clearly in the loudness and annoyance ratings of the recorded but also of the auralized sounds (see Figure 24 and Figure 25). With smaller differences, i.e. between floor 2 and 3, or between floor 3 and 4, the rating of loudness and annoyance is partially not significantly different. Insignificant differences are marked by blue brackets in Figure 24 and Figure 25. They occur with the auralized and the recorded sounds. The results of the significance tests can be found in the appendix of this report (Appendix 3 and **Error! Reference source not found.**).

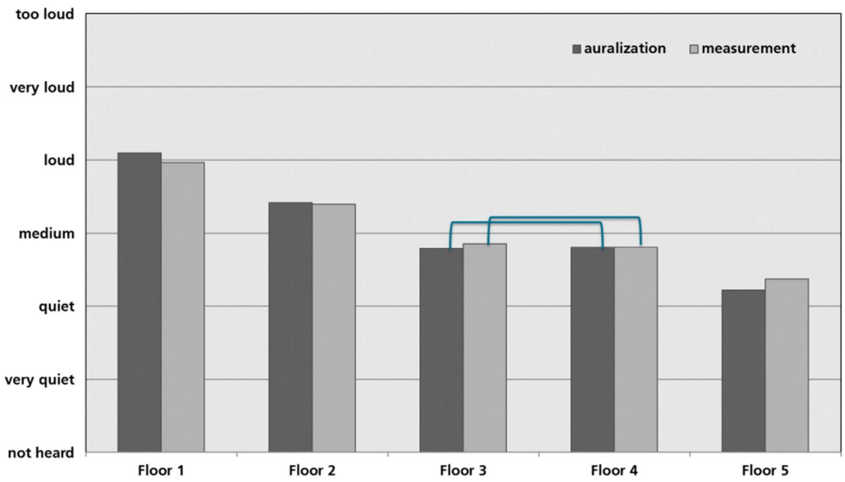


Figure 24: The diagram shows the loudness rating for the different floor constructions. Since no significant differences between the various excitation types were detected, all excitation types were averaged in the result presentation. The diagram shows the ratings for auralized and recorded sounds, averaged over all excitation types and test persons. The blue brackets mark those floor constructions that did not significantly reflect quality differences in the subjective rating.

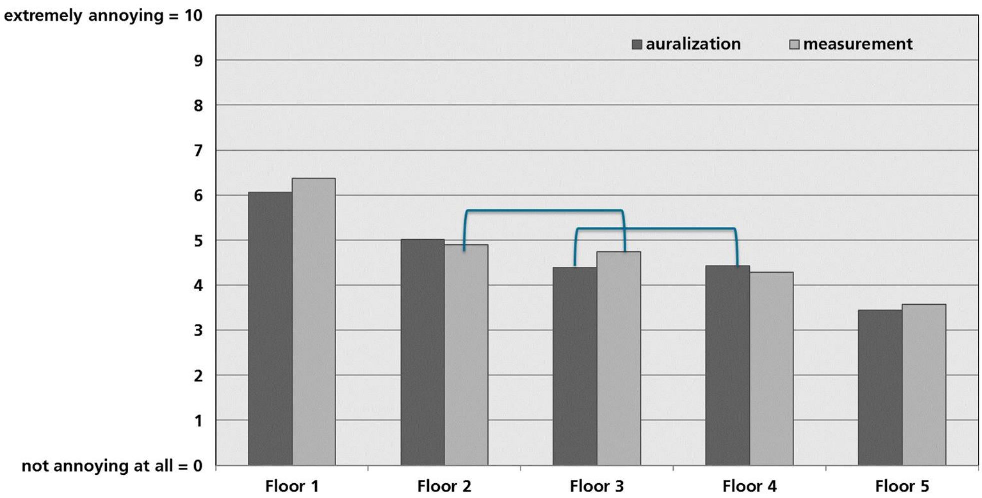


Figure 25: The diagram shows the annoyance rating for the different floor constructions. Since no significant differences between the various excitation types were detected, all excitation types were averaged in the result presentation. The diagram shows the ratings for auralized and recorded sounds, averaged over all excitation types and test persons. The blue brackets mark those floor constructions that did not significantly reflect quality differences in the subjective rating.

4.2.3.3 Comparison: Octaves / third octaves / single values

In order to examine which influence the database available for the auralization (few information = single value of the floor construction is available; a lot of information = third octave values of the floor construction are available) has on the auditory impression, all four excitation types (rubber ball, tapping machine, chair pulling and male walker) were auralized. Using octave values, third octave values and single values, the auralization was either based on floor 2 or on the reference curve. Thus, it was intended to examine whether an auralization based on a single value results in the same auditory impression as an auralization based on third octaves, and hence whether the auralization tool may also be used with only a low data availability. With regard to the sounds auralized on the basis of the reference curve (floor 6 – floor 8 in Table 4), there is no difference to be expected when comparing the sounds auralized on the basis of single values, octave values and third octave values, since subtracting out the reference curve does not make a difference. Thus, the sounds auralized on different bases (third octave or octave) are only slightly different.

When using for the auralisation not the reference curve, but the described floor constructions, differences in the perception because of different data availability is to be expected. For the auralisation on the basis of single number values, less information is available and the auralized sound might lead to a (distinctive) different perception, compared to the original sound of this floor.

Figure 26 and Figure 27 show the results of the loudness and annoyance rating for the auralized sounds based on the reference curve by help of the single values, octave values and third octave values. (floor 6 –floor 8 in Table 4). Both for the loudness and annoyance rating there were no significant differences detected.

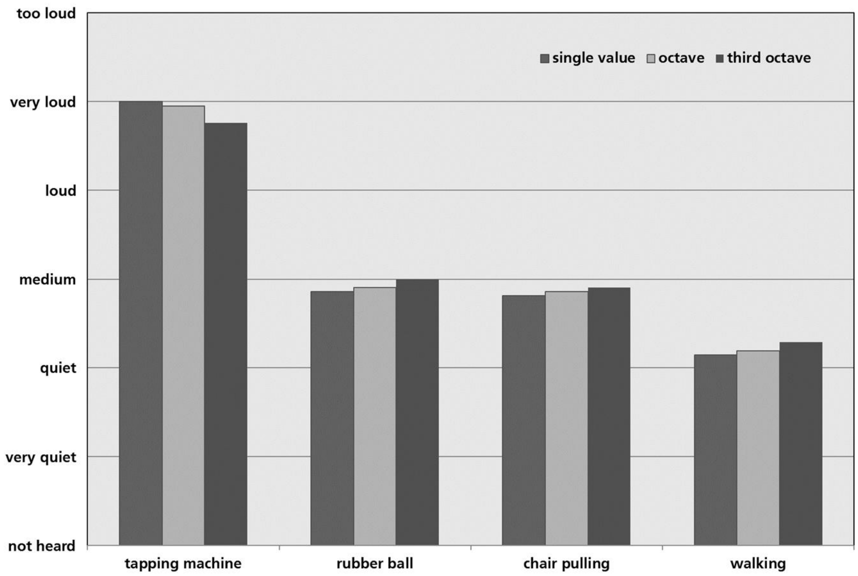


Figure 26: Auralization based on reference curve. In the figure, the loudness ratings averaged over all test persons are presented for all excitation types. For comparison purposes, the subjective loudness ratings for the auralizations with single, third octave and octave values are presented (floor 6 – floor 8 in Table 4).

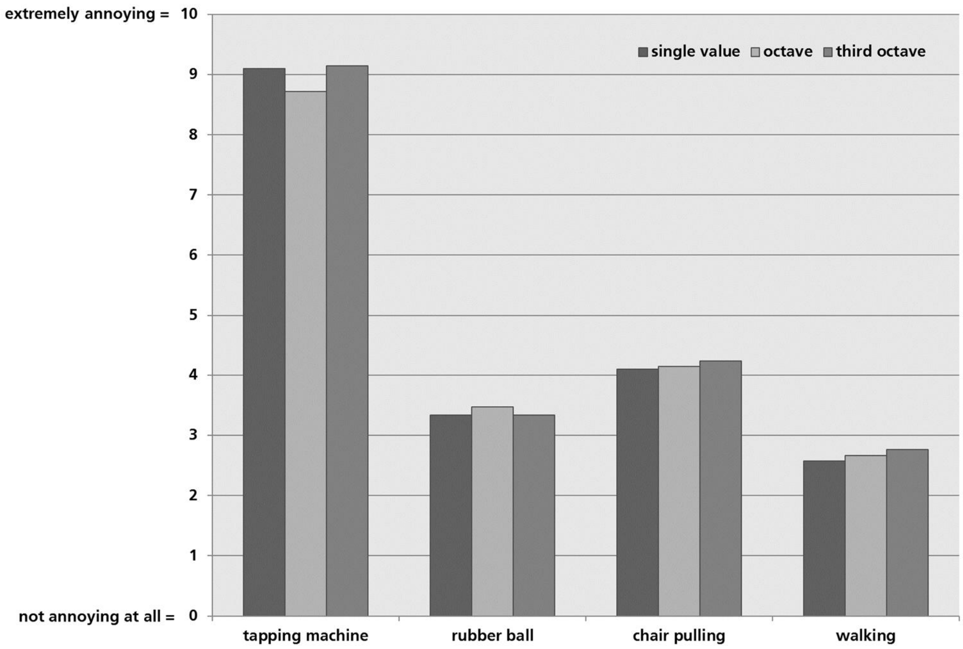


Figure 27: Auralization based on reference curve. In the figure, the annoyance ratings averaged over all test persons are presented for all excitation types. For comparison purposes, the subjective loudness ratings for the auralizations with single, third octave and octave values are presented (floor 6 – floor 8 in Table 1).

However, if the auralization is not based on the reference curve, but on one of the described floor constructions, differences in perception due to a differing data availability are to be expected. Since for an auralization based on single values considerably less information is entered, the created sounds can result in a (significantly) different auditory impression. Of particular interest here is the comparison with the perception of the recorded original sound. Figure 28 and Figure 29 show the results of the loudness and annoyance ratings of the sounds auralized on the basis of floor 2 with availability of single values, third octave values and octave values. Still only a few significant perception differences were found here. Especially the perception differences between the auralized sounds based on single values or octave values and the original recordings are relevant (low data availability). Such significant differences did occur only in the loudness rating, but not in the annoyance rating. For the tapping machine (auralization with octave values vs. original recording: $t(20) = 2.609$, $p < .05$) and for the ball (auralization with single value vs. original recording: $t(20) = -2.359$, $p < .05$; auralization with octave values vs. original recording: $t(20) = -2.320$, $p < .05$) the auralization based on octave values was rated to be significantly different compared to the original recording.

As to the ball, this was also the case for the auralization based on single number values. As already mentioned, the perceived and the actual loudness correlate very highly, which indicates that perceived loudness differences are also present objectively. Also in the annoyance rating a significant difference was found Figure 29; $t(20) = 2.142$, $p <.05$), but in the context of practical application this difference is less relevant, because it is a difference between the auralization with single values and the auralization with octave values, but not for differences between auralized and original sounds.

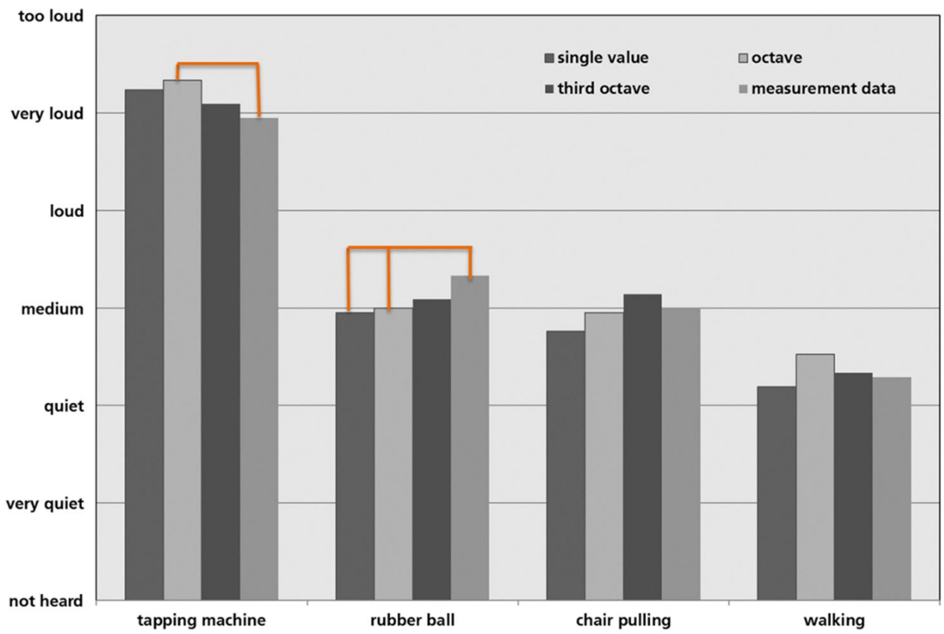


Figure 28: Auralization based on floor 2. The figure shows the loudness ratings, which are averaged over all test persons, for all excitations. For comparison purposes, subjective loudness ratings are presented for auralizations with single, third octave and octave values (floor 9, floor 2 and floor 10 in Table 1). The orange brackets show significant differences between the conditions in the loudness evaluation.

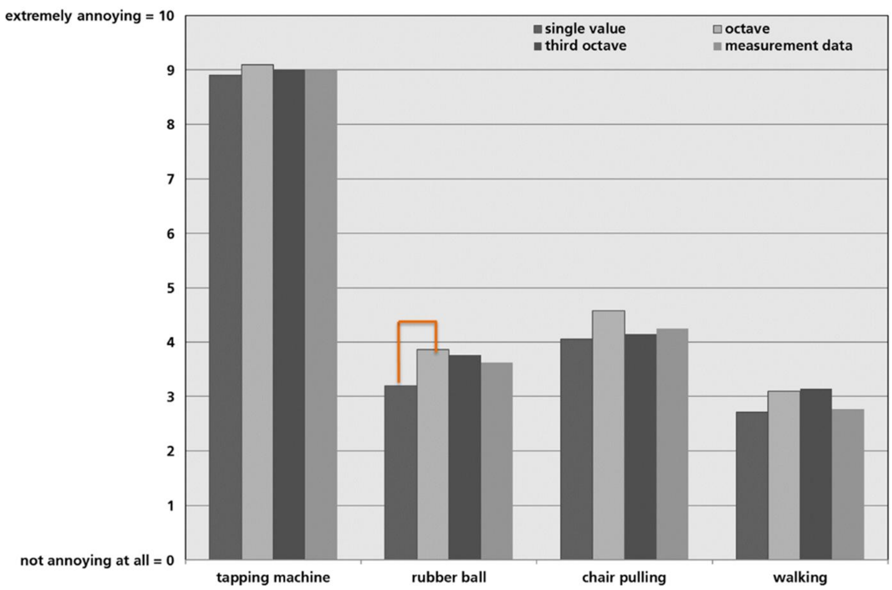


Figure 29: Auralization based on floor 2. The figure shows the annoyance judgments for all stimuli, which are averaged over all test persons. For comparison purposes, subjective ratings are presented for auralizations with single, third and octave values (floor 9, floor 2 and floor 10 in Table 1). The orange brackets show significant differences between the conditions in the annoyance assessment.

4.2.4 Discussion

Regarding the criteria of loudness and annoyance, perception differences between the auralized and the recorded sound (not for floor 2) are evident in certain floor constructions and certain excitations (mainly for the rubber ball). This can partly be explained by actual loudness differences between auralized and measured sound (which are also reflected in the annoyance ratings), and partly by the difficulty of the auralization and evaluation of short impulse containing sounds such as the rubber ball. The original level and perceived level are found to correlate highly. This indicates a high internal validity of the test arrangement.

Methodically, it would also have been possible to carry out a pairwise comparison. This might have produced less coherent results, since two sounds are compared directly with each other and are evaluated in terms of equality or inequality. However, for the purpose the auralization is intended to be applied to in practice, the selection of a suitable floor construction with acoustic properties individually perceived as the best, it is less relevant whether auralized sound and original recordings sound identically, but whether they are perceived as comparable annoying and loud. Annoyance and loudness were measured using standardized scales 0[2].

The fact that the rubber ball has proven to be problematic in the project progression in many aspects should be taken into account when selecting the noise for the online database. One of the problems is that only a limited dynamic range is available for the auralization. The three other excitation types (walking, chair pulling and tapping machine) can be well arranged in one dynamic range. The "rubber ball", on the other hand, does not match the dynamic range used for the other three excitation types, and is therefore overmodulated during the auralization process. If the "rubber ball" is included in a separate dynamic range, the comparability of the sounds is getting lost.

A further problem with the evaluation of the rubber ball sounds is that they are very short compared to the tapping machine sounds. Therefore, the rating cannot be made until the playback has finished. In addition, due to the shortness, a preceding portion of "silence" is integrated into the sound files, which can be perceived as noise, depending on the used transmission path, and could thus influence the evaluation.

However, research has shown that the rubber ball compared to the tapping machine reflects much better the everyday real impact noise in building contexts. When using a tapping machine, people who are not acoustics experts cannot get an impression of how the floor construction performs in everyday use because the standardized measuring noises sometimes have little to do with realistic noise conditions in everyday life. Thus, for the auralization tool, it must be decided carefully who is to be addressed to and what kind of noise is the best in this context.

With regard to the gradations of quality of the floor constructions tested, the listening test results show that the auralizations are reflecting the sound insulation performance of the different floors. The differences between the different floor constructions are perceived just as accurate as in the original recordings (with only one floor pair where no difference is heard). Differences cannot be heard if the difference in quality (impact sound pressure level) is only a few dB.

Concerning loudness and annoyance, floor 1, floor 3 and floor 5 can be clearly distinguished from one another. The distinction between floors 2, 3 and 4 is not always unambiguous in the listening test, but the floors are also not highly differing with respect to the impact sound pressure level.

In addition, the perception of loudness and annoyance corresponded to the actual floor quality defined by impact sound pressure (in the case of floors with a higher impact sound pressure level the different stimuli were judged to be more annoying and louder than in floors with a lower impact sound pressure level). Not only the differences between the floor structures were perceived, but also a "correct" ranking of the floors was formed according to their insulation performance. This was also the case both in the original recordings and in the auralized sounds.

For the use of the auralization tool in practice, it needs to be discussed how large the difference between the various floor constructions provided as auralization should be, and whether audible differences represent the criterion for "difference" or "equality". Furthermore, it should be considered that the sound pressure level alone is probably not the right measure to predict the audible differences.

If the reference curve is used as basis for the auralization, no significant differences in the perceived loudness and annoyance with the different kinds of data availability are to be expected (information content: single value, octaves, third octaves). The different summing in third octave or octave bands leads to different sounds. However, these results are still interesting, since they can be seen as evidence for constancy in the rating of the subjects. If a subject's rating behavior varies greatly regardless of the sound played back, we would get highly different loudness and annoyance ratings for the same sound files from one person.

If not only the reference curve serves as basis for the auralization but also floor 2, differences between sounds auralized with high and low information content are to be expected. This was also reflected in the listening test (observed trends and partly significant differences). This result suggests that auralizations for which only a single value is available, possibly may not lead to the intended hearing impression.

4.3 Volume calibration

In order that the auralization tool can be provided to users at home on their own PC and with their individual transmission path (e.g. headphones, simple speakers, laptop speakers, sound system), it is important to control the setting of the correct volume level "from the distance". If the level is set too low, differences between the floor structures may be not perceived, while a high level may lead to an overestimation of the differences or the actual sound insulation of the floor structure. The level must therefore be the same on any PC and should be calibrated with each transmission path, so that the sounds can be reproduced at a realistic volume level. To determine how this can be guaranteed best, two methods of volume calibration were compared in the second part of the listening test.

4.3.1 Calibration via speaker level

4.3.1.1 Introduction

One of the methods tested for volume calibration is the calibration via speaker level. This method is based on the assumption that people are able to (due to their experience) estimate the loudness of a speaker in a predefined conversational situation very accurately. In the listening test the level of this capacity was investigated. Assuming that the levels set by the test persons vary only slightly and match the typical conversation loudness (about 60dB (A) according to ISO 3382-3), it is possible, based on this assessment by the user, to calculate the right level for the playback of the auralized sounds in the user's PC.

All subjects participating in the listening test part 1 (noise evaluation) described above also participated in the listening tests for volume calibration.

4.3.1.2 Method

Figure 30 shows the test program, with which the subjects performed the volume calibration. The subjects were instructed to play a speech signal (played back through headphones) and then increase the volume level of this speaker signal using the arrow keys on the keyboard to the (system) volume level that appears to fit a typical conversational situation for them. At the beginning of the adjustment the system volume was zero. It was possible to set values between 30.7 and 80.1 dB (A).

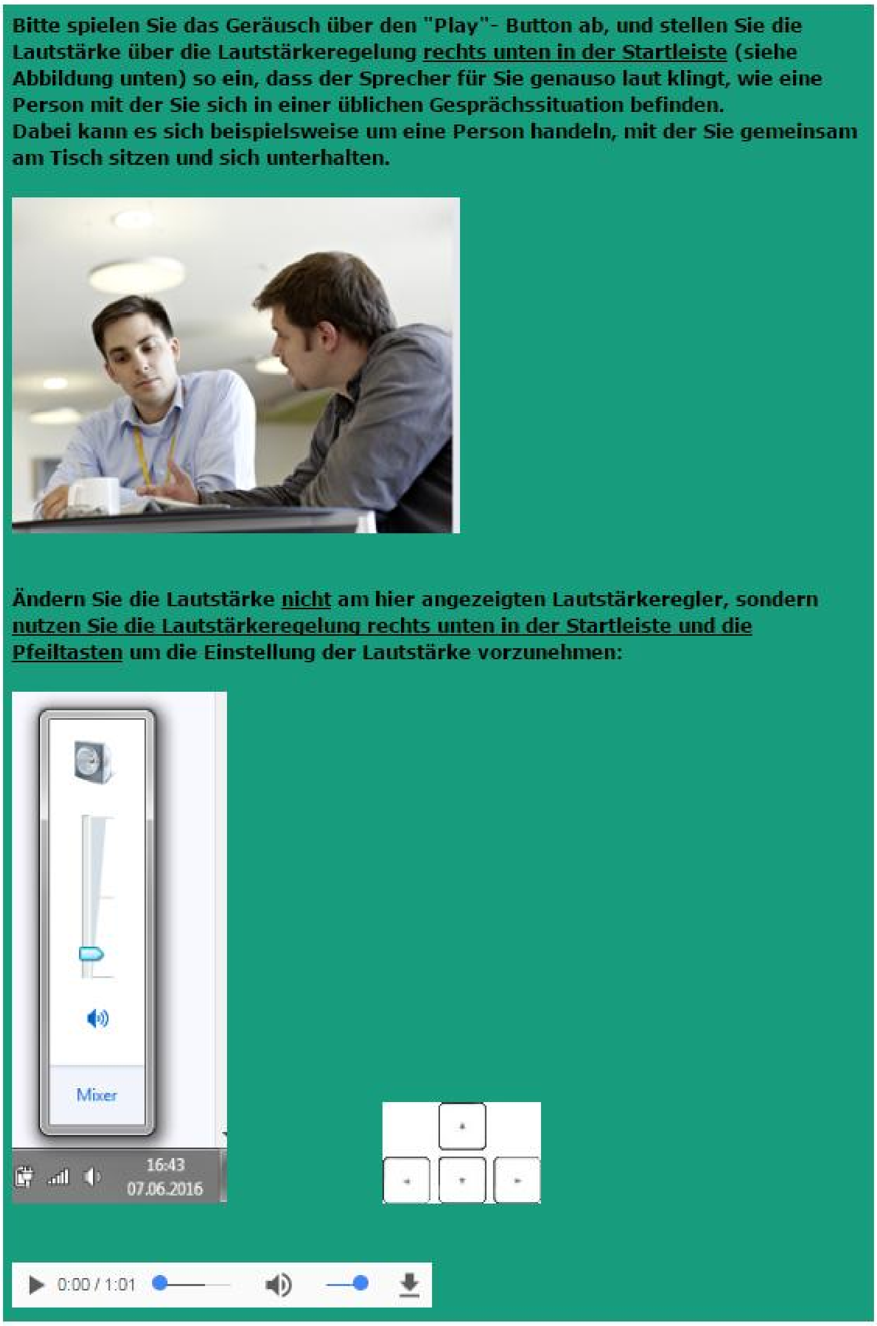


Figure 30: Test program for volume calibration via speaker level.

The distinction made by the subjects (system setting) was written down by the examiner. The system setting values have been translated into dB(A) values by help of a measurement with an artificial ear in the anechoic chamber.

4.3.1.3 Results

The results of the loudness calibration via speaker level are shown in Figure 31.Subjects were sorted according their set level in ascending order in Figure 31. The levels are also shown in the figure. On average, 49.4 dB (A) were adjusted. The standard deviation was 5.7 dB (A).

The settings varied widely among the test persons. The largest difference between two set values was about 20 dB (A). The values were all (mostly significantly) below 60dB (A), which is much too low for conversational speaker volume [3].

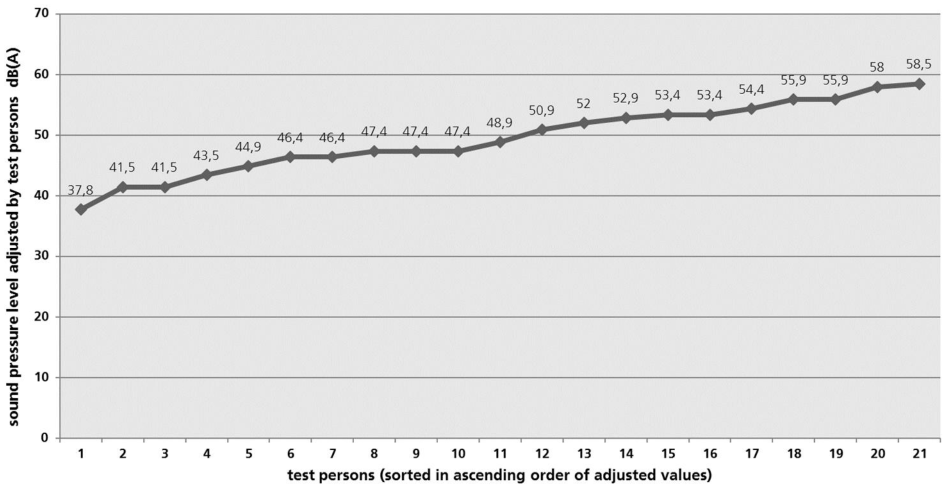


Figure 31: The graph shows the values set by the test subjects in the volume calibration via speaker level. Each data point represents a subject. The values were sorted in ascending order of the selected levels.

4.3.1.4 Discussion

Despite the strong variation between the test subjects and the rather low set levels, the method of volume calibration via speaker level has the advantage of simple and fast implementation and realization. To gain more experience with the method, a larger number of subjects should be tested using the method. Furthermore, any possibly, existing correlations, for example between individual speech volume (male vs. female) and the adjustment, are to be evaluated.

4.3.2 Calibration via hearing threshold

4.3.2.1 Introduction

The second method, the volume calibration via hearing threshold is based on the assumption that the correct volume of the auralized sounds can be calculated from the individual hearing threshold of the user and adjusted via the system volume of the PC. This method is significantly more complex than the calibration via speaker level with regard to implementation and realization.

4.3.2.2 Method

Figure 32 shows the test program the hearing threshold measurement was conducted with. The participants had the task to respond as quickly and accurately as possible to the headphone noise played back. Here noises with descending and ascending loudness were presented in randomized order. If it is a descending noise, the subjects were given the task to deliver a mouse click, once that they did not hear the sound any longer. For ascending sounds, the object was, however, to react with a mouse click once the noise can be heard for the first time. On the screen it was displayed which reaction currently was required. At the beginning the task was practiced. Then 40 trials of the task were completed. After 20 trials the noise type changed. Two types of noise were tested (noise and triad) to find out with which noise the optimal hearing threshold measurement is possible. The order of the presented types of noise varied randomly.

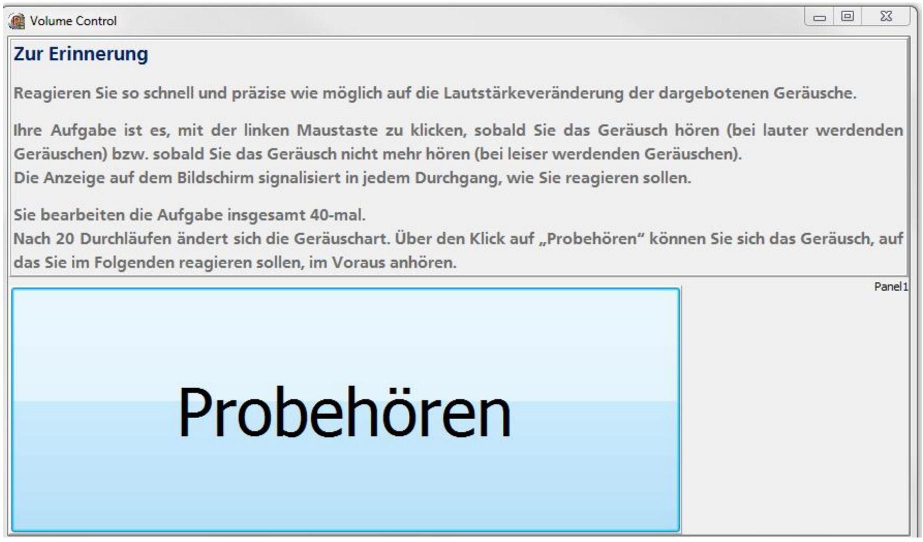


Figure 32: Test program for volume calibration via speaker level

4.3.2.3 Results

To translate the test persons' adjustments in the system settings of the iMacs into dB(A) values, a measurement in the anechoic chamber was conducted. Due to this measurement a dB(A) equivalent for every possible (system) volume setup is available for the sound files used in the listening test.

The transferred results of the hearing threshold measurement are depicted in Table 5 and Figure 33. Table 5 shows the hearing thresholds for both noise types averaged over all trials and test persons. Ascending, descending and the averaged values of ascending and descending sounds are represented separately. The standard deviation and the range of the measured hearing thresholds for the 18 test persons is also described in Table 5.

Figure 33 shows the averaged (ascending and descending) values for each test person for the two sound types. Test persons are sorted in ascending order due to their hearing threshold.

Three test persons did not completely finish this test. The data of these test persons was deleted.

Table 2: The results of the calibration via hearing threshold are shown for both noise types, each for the ascending and descending measurement and the averaged values of the ascending and the descending measurement. For each of these conditions, the mean hearing threshold (average of all test persons), the related standard deviation and the range of hearing thresholds of the different test persons are given.

Sound		Mean [dB(A)]	Standard deviation [dB (A)]	Range [dB (A)]
noise	ascending	23.4	3.2	10.3
	descending	16.9	4.4	13.4
	ascending and descending	20.2	3.1	11.6
Triad	ascending	20.3	3.4	11.8
	descending	16.4	6.2	22.4
	ascending and descending	18.3	4.1	14.2

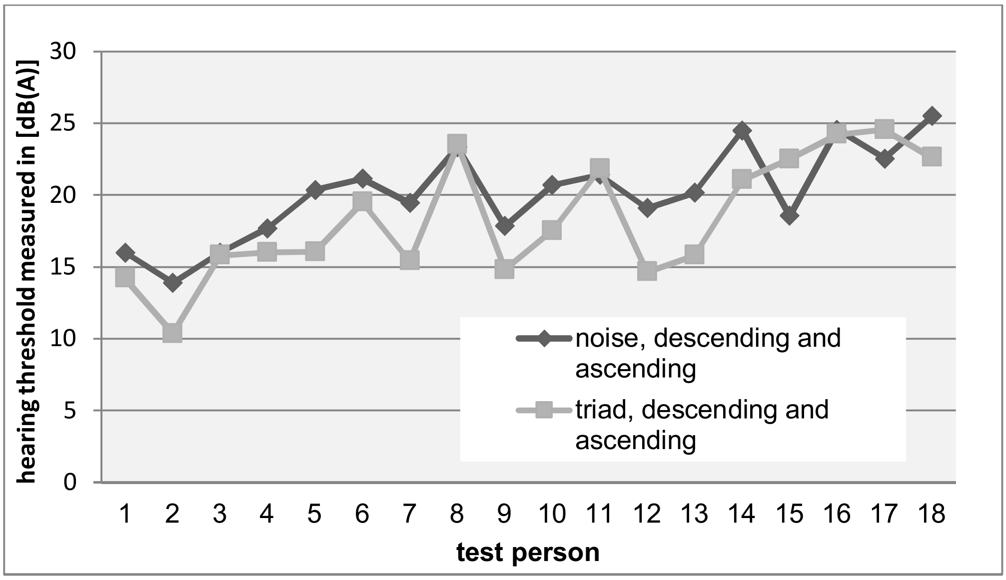


Figure 33: The graph shows the results of the hearing threshold measurement for each of the 18 test persons. The data points show the averaged values of all trials (descending and ascending) a test person has passed. Results are represented separately for the noise

4.3.2.4 Discussion

The standard deviation, which describes the differences in the ascertained volume / threshold levels, is smaller for the noise condition compared to the triad condition. Overall, the standard deviations of this calibration method are slightly better (smaller) than for the calibration via speaker level. However, the implementation effort and time exposure are considerably higher for the hearing threshold calibration method.

4.3.3 Method comparison

The accuracy (deviation of values) was slightly better with the second method, the hearing threshold measurement, than for the calibration via speaker level. The cost of implementation, realization, and the time required for the user, however, are significantly higher for the second method. Based on these data, the decision to implement the first method has been made.

4.4 Conclusions (listening test)

The listening test has delivered good results. The implementation of the auralization can be done now. Next, the volume control is implemented by means of speaker level. After that the connection to the database can be done

5 Literature

[1] ISO / TS 15666: 2003 (en): Acoustics - Assessment of noise annoyance by Means of social and socio-acoustic surveys; 2003.

[2] ISO 16832: 2006: Acoustics - Loudness scaling by Means of categories.

[3] ISO 3382-3: Acoustics - Measurement of room acoustic parameters - Part 3: Open plan offices (ISO 3382-3: 2012); German version EN ISO 3382-3: 2012

[4] Berechnung der Gehgeräusche-Immissionen und Trittschalldämmung von Geschossdecken aus Holz im Frequencybereich von 16 Hz bis 200 Hz (Forschungsarbeit vom Institut für Lärmschutz Kühn + Blickle, 6314 Unterägeri) 2004

[5] ISO 717-2:2013: Acoustics – Rating of sound insulation in buildings and of building elements – Part 2: Impact sound insulation

[6] DIN EN ISO 10140-5:2010: Acoustics – Laboratory measurement of sound insulation of building elements – Part 5: Requirements for test facilities and equipment.

[7] Oracle, What ist JavaFX?, http://docs.oracle.com/javafx/2/overview/jfxpub-overview.htm, and connected links, accessed on 8.3.2017.

6 Appendix

Appendix 1 Comparison of subjective loudness ratings for auralized and recorded sounds

Test bei gepaarten Stichproben

		Gepaarte Differenzen					T	df	Sig. (2-seitig)
		Mittelwert	Standardabweichung	Standardfehler des Mittelwertes	95% Konfidenzintervall der Differenz Untere	Obere			
Paaren 1	AU_D1_HW - ME_D1_HW	,524	,512	,112	,291	,757	4,690	20	,000
Paaren 2	AU_D1_B - ME_D1_B	-,571	,926	,202	-,993	-,150	-2,828	20	,010
Paaren 3	AU_D1_S - ME_D1_S	,333	,796	,174	-,029	,696	1,919	20	,069
Paaren 4	AU_D1_G - ME_D1_G	,238	,768	,168	-,112	,588	1,420	20	,171
Paaren 5	AU_D2_HW - ME_D2_HW	,143	,655	,143	-,155	,441	1,000	20	,329
Paaren 6	AU_D2_B - ME_D2_B	-,238	,768	,168	-,588	,112	-1,420	20	,171
Paaren 7	AU_D2_S - ME_D2_S	,143	,910	,199	-,271	,557	,719	20	,480
Paaren 8	AU_D2_G - ME_D2_G	,048	,590	,129	-,221	,316	,370	20	,715
Paaren 9	AU_D3_HW - ME_D3_HW	,190	,814	,178	-,180	,561	1,073	20	,296
Paaren 10	AU_D3_B - ME_D3_B	-1,333	1,065	,232	-1,818	-,849	-5,739	20	,000
Paaren 11	AU_D3_S - ME_D3_S	,476	,680	,148	,167	,786	3,211	20	,004
Paaren 12	AU_D3_G - ME_D3_G	,381	1,071	,234	-,107	,869	1,630	20	,119
Paaren 13	AU_D4_HW - ME_D4_HW	,000	,632	,138	-,288	,288	,000	20	1,000
Paaren 14	AU_D4_B - ME_D4_B	,000	,837	,183	-,381	,381	,000	20	1,000
Paaren 15	AU_D4_S - ME_D4_S	-,476	,750	,164	-,817	-,135	-2,911	20	,009
Paaren 16	AU_D4_G - ME_D4_G	,476	,680	,148	,167	,786	3,211	20	,004
Paaren 17	AU_D5_HW - ME_D5_HW	,095	,625	,136	-,189	,380	,698	20	,493
Paaren 18	AU_D5_B - ME_D5_B	-,524	,873	,190	-,921	-,126	-2,750	20	,012
Paaren 19	AU_D5_S - ME_D5_S	-,381	,865	,189	-,775	,013	-2,019	20	,057
Paaren 20	AU_D5_G - ME_D5_G	,190	,402	,088	,007	,374	2,169	20	,042

Appendix 2: Comparison of subjective annoyance ratings for auralized and recorded sounds

Test bei gepaarten Stichproben

		Gepaarte Differenzen					T	df	Sig. (2-seitig)
		Mittelwert	Standardabweichung	Standardfehler des Mittelwertes	95% Konfidenzintervall der Differenz Untere	Obere			
Paaren 1	AU_D1_HW - ME_D1_HW	,143	,910	,199	-,271	,557	,719	20	,480
Paaren 2	AU_D1_B - ME_D1_B	-1,333	1,713	,374	-2,113	-,554	-3,568	20	,002
Paaren 3	AU_D1_S - ME_D1_S	-,714	2,077	,453	-1,660	,231	-1,576	20	,131
Paaren 4	AU_D1_G - ME_D1_G	,619	1,627	,355	-,122	1,360	1,743	20	,097
Paaren 5	AU_D2_HW - ME_D2_HW	,000	1,049	,229	-,477	,477	,000	20	1,000
Paaren 6	AU_D2_B - ME_D2_B	,143	2,007	,438	-,771	1,056	,326	20	,748
Paaren 7	AU_D2_S - ME_D2_S	-,095	1,814	,396	-,921	,730	-,241	20	,812
Paaren 8	AU_D2_G - ME_D2_G	,381	1,161	,253	-,147	,909	1,504	20	,148
Paaren 9	AU_D3_HW - ME_D3_HW	,476	1,289	,281	-,111	1,063	1,693	20	,106
Paaren 10	AU_D3_B - ME_D3_B	-1,524	1,778	,388	-2,333	-,714	-3,927	20	,001
Paaren 11	AU_D3_S - ME_D3_S	,095	1,700	,371	-,679	,869	,257	20	,800
Paaren 12	AU_D3_G - ME_D3_G	-,524	1,965	,429	-1,418	,371	-1,221	20	,236
Paaren 13	AU_D4_HW - ME_D4_HW	-,095	1,221	,266	-,651	,460	-,357	20	,724
Paaren 14	AU_D4_B - ME_D4_B	,095	1,895	,413	-,767	,958	,230	20	,820
Paaren 15	AU_D4_S - ME_D4_S	-,381	1,532	,334	-1,078	,316	-1,139	20	,268
Paaren 16	AU_D4_G - ME_D4_G	,952	1,161	,253	,424	1,481	3,760	20	,001
Paaren 17	AU_D5_HW - ME_D5_HW	,095	,995	,217	-,358	,548	,439	20	,666
Paaren 18	AU_D5_B - ME_D5_B	,095	1,578	,344	-,623	,814	,277	20	,785
Paaren 19	AU_D5_S - ME_D5_S	-,857	1,740	,380	-1,649	-,065	-2,257	20	,035
Paaren 20	AU_D5_G - ME_D5_G	,143	1,062	,232	-,341	,626	,616	20	,545

Appendix 3: Comparison of subjective loudness ratings for different floor constructions

Test bei gepaarten Stichproben									
		Gepaarte Differenzen					T	df	Sig. (2-seitig)
					95% Konfidenzintervall der Differenz				
		Mittelwert	Standardabweichung	Standardfehler des Mittelwertes	Untere	Obere			
Paaren 1	AU_D1 - AU_D2	,67857	,46194	,10080	,46830	,88885	6,732	20	,000
Paaren 2	AU_D1 - AU_D3	1,30952	,45349	,09896	1,10310	1,51595	13,233	20	,000
Paaren 3	AU_D1 - AU_D4	1,28571	,44219	,09649	1,08443	1,48700	13,324	20	,000
Paaren 4	AU_D1 - AU_D5	1,88095	,44454	,09701	1,67860	2,08331	19,390	20	,000
Paaren 5	AU_D2 - AU_D3	,63095	,43025	,09389	,43510	,82680	6,720	20	,000
Paaren 6	AU_D2 - AU_D4	,60714	,35857	,07825	,44392	,77036	7,759	20	,000
Paaren 7	AU_D2 - AU_D5	1,20238	,44454	,09701	1,00003	1,40473	12,395	20	,000
Paaren 8	AU_D3 - AU_D4	-,02381	,47371	,10337	-,23944	,19182	-,230	20	,820
Paaren 9	AU_D3 - AU_D5	,57143	,42678	,09313	,37716	,76570	6,136	20	,000
Paaren 10	AU_D4 - AU_D5	,59524	,34889	,07613	,43642	,75405	7,818	20	,000

Comparison of subjective loudness ratings for different floor constructions

Test bei gepaarten Stichproben									
		Gepaarte Differenzen					T	df	Sig. (2-seitig)
					95% Konfidenzintervall der Differenz				
		Mittelwert	Standardabweichung	Standardfehler des Mittelwertes	Untere	Obere			
Paaren 1	ME_D1 - ME_D2	,57143	,35481	,07743	,40992	,73294	7,380	20	,000
Paaren 2	ME_D1 - ME_D3	1,10714	,64017	,13970	,81574	1,39855	7,925	20	,000
Paaren 3	ME_D1 - ME_D4	1,15476	,45741	,09982	,94655	1,36297	11,569	20	,000
Paaren 4	ME_D1 - ME_D5	1,59524	,48397	,10561	1,37494	1,81554	15,105	20	,000
Paaren 5	ME_D2 - ME_D3	,53571	,50797	,11085	,30449	,76694	4,833	20	,000
Paaren 6	ME_D2 - ME_D4	,58333	,45644	,09960	,37557	,79110	5,857	20	,000
Paaren 7	ME_D2 - ME_D5	1,02381	,43232	,09434	,82702	1,22060	10,852	20	,000
Paaren 8	ME_D3 - ME_D4	,04762	,43746	,09546	-,15151	,24675	,499	20	,623
Paaren 9	ME_D3 - ME_D5	,48810	,33982	,07415	,33341	,64278	6,582	20	,000
Paaren 10	ME_D4 - ME_D5	,44048	,29480	,06433	,30629	,57467	6,847	20	,000

Appendix 4: Comparison of subjective annoyance rating for different floor constructions

Test bei gepaarten Stichproben

		Gepaarte Differenzen							
					95% Konfidenzintervall der Differenz				
		Mittelwert	Standardabweichung	Standardfehler des Mittelwertes	Untere	Obere	T	df	Sig. (2-seitig)
Paaren 1	AU_D1 - AU_D2	1,04762	,78110	,17045	,69207	1,40317	6,146	20	,000
Paaren 2	AU_D1 - AU_D3	1,67857	1,06402	,23219	1,19423	2,16291	7,229	20	,000
Paaren 3	AU_D1 - AU_D4	1,64286	,80067	,17472	1,27840	2,00732	9,403	20	,000
Paaren 4	AU_D1 - AU_D5	2,61905	,82772	,18062	2,24227	2,99582	14,500	20	,000
Paaren 5	AU_D2 - AU_D3	,63095	1,09150	,23818	,13411	1,12780	2,649	20	,015
Paaren 6	AU_D2 - AU_D4	,59524	,65420	,14276	,29745	,89303	4,170	20	,000
Paaren 7	AU_D2 - AU_D5	1,57143	,82969	,18105	1,19376	1,94910	8,679	20	,000
Paaren 8	AU_D3 - AU_D4	-,03571	,78774	,17190	-,39429	,32286	-,208	20	,838
Paaren 9	AU_D3 - AU_D5	,94048	,87287	,19048	,54315	1,33780	4,938	20	,000
Paaren 10	AU_D4 - AU_D5	,97619	,80197	,17500	,61114	1,34124	5,578	20	,000

Comparison of subjective annoyance rating for different floor constructions

Test bei gepaarten Stichproben

		Gepaarte Differenzen							
					95% Konfidenzintervall der Differenz				
		Mittelwert	Standardabweichung	Standardfehler des Mittelwertes	Untere	Obere	T	df	Sig. (2-seitig)
Paaren 1	ME_D1 - ME_D2	1,47619	,58043	,12666	1,21198	1,74040	11,655	20	,000
Paaren 2	ME_D1 - ME_D3	1,63095	,95400	,20818	1,19670	2,06521	7,834	20	,000
Paaren 3	ME_D1 - ME_D4	2,10714	1,02033	,22265	1,64269	2,57159	9,464	20	,000
Paaren 4	ME_D1 - ME_D5	2,80952	1,23720	,26998	2,24636	3,37269	10,406	20	,000
Paaren 5	ME_D2 - ME_D3	,15476	1,07377	,23432	-,33401	,64353	,660	20	,516
Paaren 6	ME_D2 - ME_D4	,63095	,85007	,18550	,24401	1,01790	3,401	20	,003
Paaren 7	ME_D2 - ME_D5	1,33333	1,17349	,25608	,79917	1,86750	5,207	20	,000
Paaren 8	ME_D3 - ME_D4	,47619	1,00593	,21951	,01829	,93409	2,169	20	,042
Paaren 9	ME_D3 - ME_D5	1,17857	1,14876	,25068	,65566	1,70148	4,702	20	,000
Paaren 10	ME_D4 - ME_D5	,70238	,83897	,18308	,32049	1,08428	3,837	20	,001

7 Figures

8 Tables

9 Annex

Annex 1. Implementation Auralization HS170720

Implementation Auralization

1. Instructions for using the Auralization over the web

Stuttgart, 15.03.2017, MoS

2. Link to the web application:

Auralization of 10 floors from the listening test:
http://auralisation.ibp.fraunhofer.de/lgn/JAuralisation07032017/JavaAuralisation.html

Auralization for Lignum with AB _ comparison possibility:
http://auralisation.ibp.fraunhofer.de/lgn/JAuralisation07032017/JavaAuralisationLignum.html

Because the application is not signed, it is necessary to make an exception, otherwise the use of Java is blocked. The following steps must therefore be performed:

1. Copy the path in Firefox or Windows Explorer
   Search in Start / All Programs for "Java" or starting the Java (32-bit) control panel in the Control Panel
2. Selecting Java (32-bit)
3. On Java Control panel selection security
4. Edit exception list site list
5. Obiger path add Java Control panel OK
6. presswebsite exception permit
7. for noise (best with headphones)

In the auralization Lignum different auralizations "set parameters" can be entered. These are intended to simulate the repeated calls of "Auralization" from the database. The various parameter sets are stored locally in a cookie, so that it is possible to a back and forth between the various auralizations.

Possible inputs

3. The single value

E 58 to E 70 .... (Space not forget) based on various auralizations on Einzahlwerten (E)

4. Third Octaves

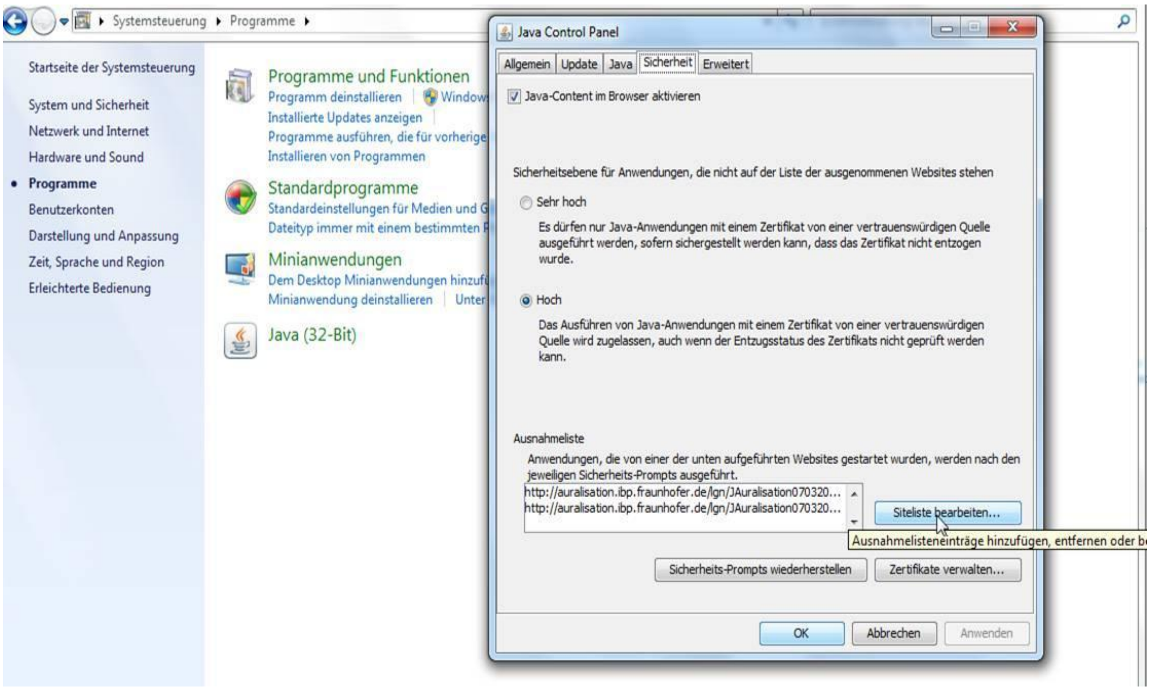
T 50 68 71 74 72 74 74 70 72 68 68 66 64 58 53 48 45 42 43 39 30 19 (ceiling 1 from listening test in thirds (T))

5. Octaves

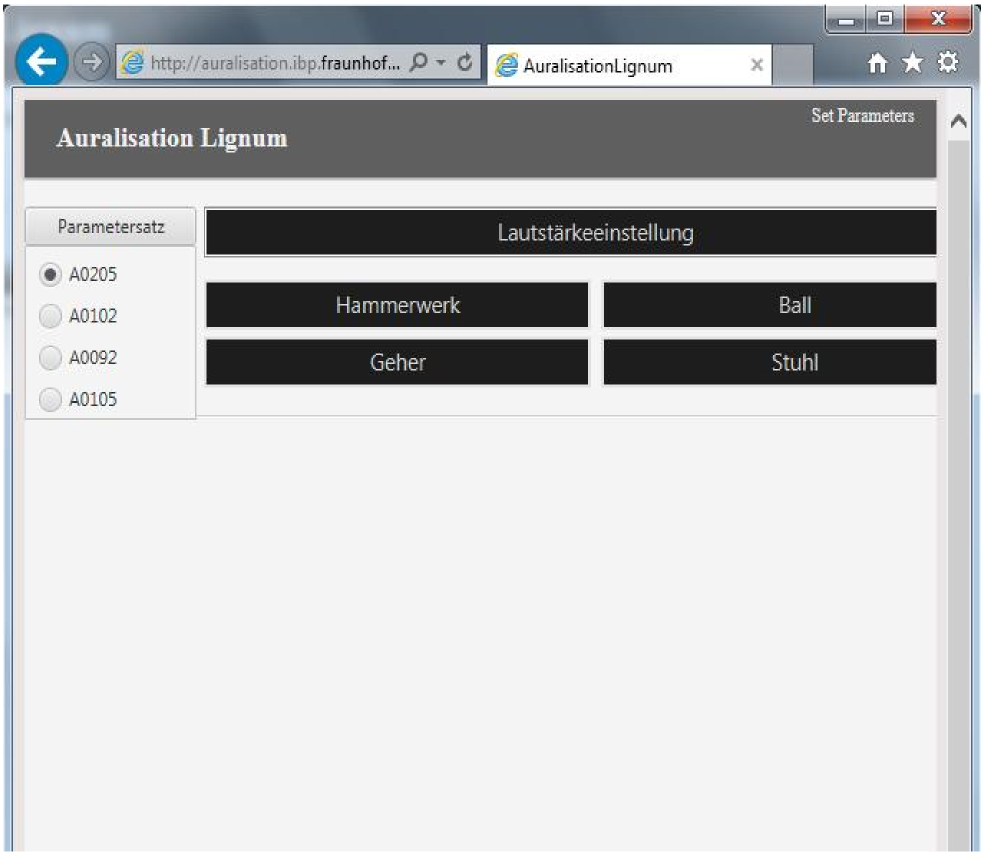
o 63 71 70 66 61 59 54ceiling 2 in octaves (O))

The records can be changed by the effect of the auralization try.

6. Setting for Java



7. Auralization for Lignum



8. Integrated Implementation graphically

The integrated implementation is for the time being in the preview version. Entitled **"Auralization / selection"**

10. Info field

The volume setting If an info box with teaser as the setting to make is this text comes into the system texts.

11. Confirm

Before the Auralization can be carried out must (information to be clicked one check mark in a box read and set volume).

12. Select and deselect

Each component has a field for selecting the Auralization. In the parameter set (selection Aura IntelliStation) A maximum of 12 records can be set. you can through a field again can be deleted from the selection. Additionally, selected all select parts can be displayed together. (selection close Show / selection). This is not part of the auralization.

Silent Timber Build

The overall objectives of Silent Timber Build project are to develop prediction models for multi storey buildings using various wooden floor and wall assemblies in the structural elements.