

ACOUSTIC CONSIDERATIONS IN THE POST-RENOVATION PHASE OF INDUSTRIAL HERITAGE ADAPTIVE REUSE: A CASE STUDY IN SHANKANGLI, SHANGHAI

DOI: https://doi.org/10.18485/arh_pt.2025.10.ch75

_ Yizhou Tang

PhD student, Faculty of Engineering and Information Technology Institution, University of Pécs, Pécs, Hungary, tang.yizhou@edu.pte.hu, [0009-0008-9732-1025]

_ Miklós Halada

PhD, Associate Professor, Faculty of Engineering and Information Technology Institution, University of Pécs, Pécs, Hungary, halada.miklos@mik.pte.hu, [0000-0002-2476-4721]

_ Péter Paári

PhD, Assistant Professor, Faculty of Engineering and Information Technology Institution, University of Pécs, Pécs, Hungary, paari.peter@mik.pte.hu, [0000-0002-8811-4357]

_ Hanxiao Li

DLA student, Faculty of Engineering and Information Technology Institution, University of Pécs, Pécs, Hungary, lihanxiao@mail.com, [0009-0006-9662-7423]

ABSTRACT

This study focuses on the acoustic considerations in the adaptive reuse of industrial heritage buildings. The meeting room of Project R in Shankangli, Shanghai, China, was selected as the subject of the research. A method was proposed that preserves the industrial aesthetic while enabling precise control of reverberation time up to the frequency level. A type of sandwich sound-absorbing panel consisting of rockwool, air gaps, and fabric-upholstery was applied, with profiles combined to form an integrated wall-mounted sound absorption system. By sampling the sound sources and analyzing the frequency characteristics, the density of the rockwool and cavity thickness were optimized to achieve targeted control of reverberation time at specific frequency bands. Measurement results showed that the reverberation time was reduced from 1.34 seconds to 0.66 seconds after renovation, meeting the acoustic standards for office related function. The use of cement-colored fabric for surface upholstery allowed the continuation of the industrial aesthetic. Objective measurement comparisons from before and after as well as feedback from the owner both proved the validation and feasibility of the proposed method in the actual project. This study provides valuable reference for acoustic optimization in the adaptive reuse of industrial heritage, particularly in terms of fine control of reverberation time by frequency band and the retaining of industrial aesthetics.

KEYWORDS _ *Building acoustics, industrial Heritage, frequency, reverberation control, Shankangli*

INTRODUCTION

In the process of adaptive reuse of industrial heritage buildings, integrating modern functionality while retaining the original architectural style has become a critical issue in design. With China's rapid economic growth and urbanization, the adaptive reuse of industrial heritage has emerged as a significant trend [1]. As China's economic and cultural center, Shanghai has made notable progress in industrial heritage redevelopment in recent years. Examples such as Xintiandi and M50 Art District demonstrate successful integration of industrial architecture with modern commercial and cultural activities, serving as exemplary models of urban innovation and historical continuity. According to [2], although thoughtful design and functional adaptation, Shanghai's industrial heritage sites have not only maintained their historical identity but also been successfully adapted to meet modern usage demands. However, many historical buildings and industrial sites have retained their distinctive industrial aesthetics during the renovation process. Exposed steel structures, visible pipelines, and rough-textured walls not only preserve the historical character of the buildings but also align with contemporary aesthetics. However, while this design approach enhances visual appeal, it can introduce significant acoustic challenges, particularly in highly functional spaces such as open-plan offices, auditoriums, and conference rooms. For instance, in the renovation of Shanghai No. 17 Cotton Textile Mill, which was transformed into a fashion and commercial center, severe acoustic issues, including excessive reverberation and noise disturbances, were reported in the shopping areas, negatively affecting customer experience and comfort [3]. Optimizing the acoustic environment while maintaining the original architectural character has become a critical challenge for designers.



Figure 1: Shankangli in the past and present, (Source: Photo by the Authors and colorful design [4])

Shankangli (Figure 1), in Jing'an District Shanghai, a historically significant area that has multiple functional transformations over time [4]. From 1909 to 1943, this site served as the Gordon Road Police Station. In 1915, to resolve conflicts between Sikh officers from India and other police personnel, a Sikh temple was constructed within the premises. As the foreign concessions came to an end, the area gradually evolved into a hub for national industries, leading to increasingly complex urban functions. After World War II, due to population growth and urban decline, the original buildings were repurposed, resulting in a mixed-use neighborhood comprising repair workshops and retail shops. After decades, Shankangli became a major distribution center for industrial materials. However, issues such as aging infrastructure and poor management prompted the government to initiate a redevelopment plan aimed at revitalizing the area into a modern commercial demonstration area while preserving its historical value.

The client is a young brand epitomizes Scandinavian minimalism through a reductive design philosophy characterized by monochromatic palettes, geometric forms, and an emphasis on material functionality. This ethos critically extends into its retail environments. The client's showrooms frequently occupy adaptively reused industrial structures, deliberately retaining raw architectural elements including exposed concrete, structural steel, glass and hard surfaces to their brand DNA.

However, this commitment to industrial materiality and minimalist leads to many acoustic challenges. Consequently, these environments often suffer from elevated noise levels, compromised speech intelligibility, and excessive reverberation time. This study investigates acoustic considerations during the post-renovation phase of Project R (Figure 2) in the Shankangli area. It explores strategies for optimizing the indoor sound environment within the constraints of conserving a historic industrial building and meeting contemporary functional demands through adaptive reuse.

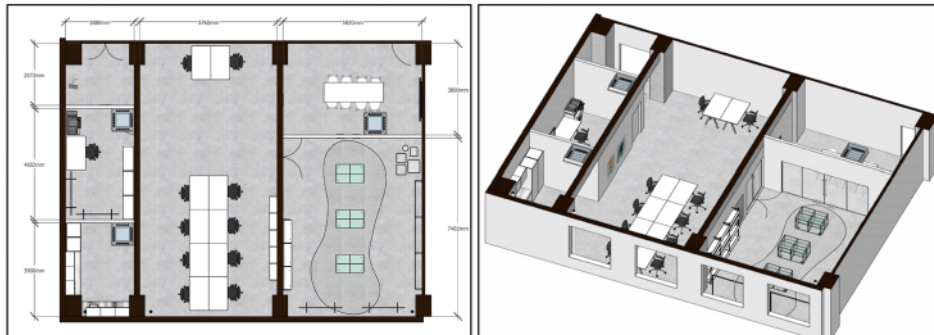


Figure 2: Floor plan and 3D model of Project R, (Source: drawings by the Authors).

METHODOLOGY

This study analyzes the acoustic renovation process of Project R, summarizing key acoustic considerations in the adaptive reuse of industrial heritage buildings. The research scope encompasses the following aspects: (1) The impact of room dimensions on acoustic characteristics, particularly echoes and reverberation time. (2) The acoustic performance of industrial-style original surface materials, evaluating their effects on absorption, reflection, and diffusion. (3) The selection of proper sound-absorbing materials, avoiding conventional porous absorbers or resonance systems breaking the balance between acoustic optimization and industrial aesthetics. (4) The acoustic requirements of different functional areas, with a focus on meeting rooms, aiming to enhance the auditory experience of end users. A combination of quantitative and qualitative research methods is employed to ensure the scientific validity and feasibility of the proposed renovation strategies.

The preliminary study of Project R

The construction drawing analysis and data collection: The showroom's final construction drawings were reviewed to obtain precise room dimensions and material specifications for the ceiling, walls, and flooring. Large parallel hard surfaces exceeding 17 meters could lead to excessive echoes. The presence of highly reflective, low-absorption materials: including concrete, glass, and metal need to be noticed. These features lead to excessive reverberation times. By integrating floor plans with material specifications, a preliminary assessment of the indoor acoustic environment of Project R was conducted.

The on-site investigation and user needs assessment: An initial site visit to Project R was conducted to figure out users' subjective perceptions of the acoustic environment and key concerns; The consistency between actual materials and design specifications was examined, along with the alignment of space utilization with its original intent and any modifications in its usage patterns; The number and gender distribution of employees were collected, as well as information on whether an amplification system was employed in the meeting room; Discussions with the owner were undertaken to select appropriate materials for acoustic modifications, with the following objectives:

improving acoustic environment; preserving the historical value of industrial heritage; and ensuring that the renovated space aligns with the minimalist brand identity.

On-Site Measurement

Acoustic Environment Measurement: A second site visit to Project R was conducted, carrying acoustic measurement instruments. The Norsonic Real Time Analyzer/Integrating Sound Level Meter (Model: Nor140, Serial No: 1406*93) was used to measure the room's reverberation time and background noise. The equipment was calibrated using the Norsonic Calibrator model CBO06 (Calibrator Serial No: 340*9). The measurement of reverberation time followed the Chinese standard GB/T 50076-2013 and the international standard ISO 3382-1-2009.

Sound Source Measurement: In addition to the acoustic environment measurement, the study also sampled sounds generated by the users within the meeting room to analyze the frequency characteristics of the sound sources. The primary sound source in Project R is human speech, with the ear as the sound receiver. Due to the pinna effect [5], a directional microphone (Model: MK4) produced by Sennheiser was chosen for sound capture. Sound sampling was processed using a Mac computer equipped with LogicProX software. An audio interface, manufactured by Audient and typed as iD14, is used as the signal conversion device to ensure high-quality and accurate sound recording and data processing. **Measurement Method:** With user consent, the collection equipment was installed in the showroom and meeting spaces to sample the typical auditory interactions. For the meeting room setup: the microphone was positioned at a height of 1.2 meters from the floor, representing the ear position of a seated person during a meeting. Sampling was conducted at distances of 1 meter, 2 meters, and 3 meters from the sound source, simulating the distance between different employees in a group meeting. Continuous sampling was conducted during the meeting, with a total sampling duration of at least 1 hour.

Acoustic strategy and constructions

Open Office and Showroom Areas: Due to the use of hard parallel surface structures for the walls and ceilings, which can easily cause strong echo phenomena, movable acoustic screens are recommended to flexibly adjust the acoustic environment while avoiding damage to the original industrial style. **Meeting Room:** Based on the measured reverberation time (Figure 6), the additional sound absorption required to achieve the ideal reverberation time was calculated using the Sabine's equation [6]. Priority was given to sound absorption treatment at the ceiling-wall junction and key reflection path positions. **Selection of absorber:** The frequency spectrum of the sampled sound source was time-sliced, and the sound pressure level of each slice was averaged to identify the characteristic frequency band of the sound source. Based on this analysis, absorptive materials were selected. **Industrial Aesthetics:** Considering the specific requirements of industrial heritage renovation, materials were selected to balance acoustic performance and aesthetic characteristics, ensuring harmony between sound absorption and the industrial style. **Design and Construction:** An easy-assembled and modular acoustic system was implemented to facilitate the installation and future maintenance.

RESULTS

The preliminary study

The construction drawings (Figure 3) of Project R contain six rooms: the reception area, sample room, pantry, open space office, showroom, and meeting room. The flooring material throughout the space consists of self-leveling concrete; the ceiling is exposed reinforced concrete; a 100mm thick light

steel gypsum board is used as partition walls; and the exterior walls are finished with plaster. The meeting room and showroom are connected by a glass door. Summary of Acoustic Requirements: (1) The Open Space Office has a depth of 11 meters. Although it is not primarily used for meetings, echo control is necessary; (2) The Showroom serves as a display area for R brand's new products. Since the exhibits consist of clothing and bags, which already have sound absorption properties, the acoustic environment is acceptable; (3) The Meeting Room measures 5.8m (width) × 3.8m (length) × 3.3m (height), with hard surface materials on the floor, ceiling, and walls. Subjectively, the reverberation time is perceived as excessive, resulting in low speech intelligibility. No sound amplification system is used, but a movable television is available for presentations and online meetings; (4) The client employs eight staff members, including six women and two men; (5) Minimalism and industrial aesthetics define the brand identity of their brand, which was a key reason for selecting Shankangli as the showroom location. The acoustic renovation must not compromise the brand style.

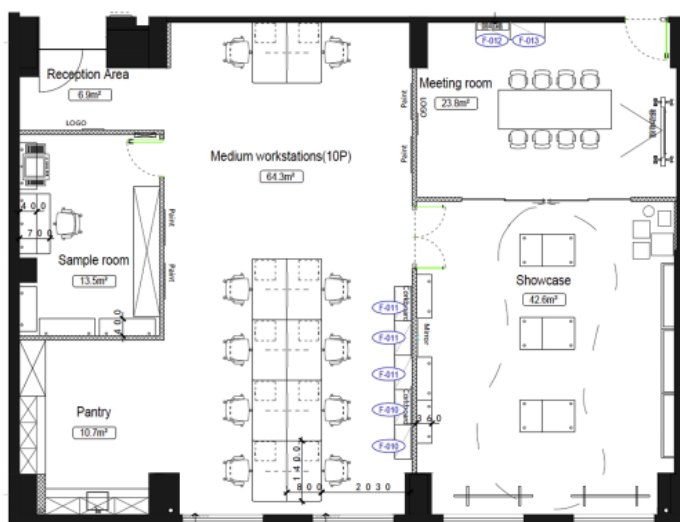


Figure 3: Floor plan of Project R, (Source: drawing by the Authors)

Acoustic Environment measurement: Figure 6 presents the reverberation time for the Meeting Room in octave bands. The average reverberation time is 1.34 seconds from octave band, with background noise level of 43 dB. Sound Source Characteristics: The results (Figure 4) of the frequency analysis indicate that the vowel sounds during meetings are primarily concentrated in 100Hz to 500 Hz, while consonant sounds are mainly within 2000Hz to 4000 Hz. This analysis provides valuable guidance for selecting appropriate acoustic materials.



Figure 4: A time frame of typical sound characteristic in frequency domain, (Souce: by the Authors)

Acoustic Design, Construction and Validation

The acoustic treatment of the meeting room needed to balance both acoustic performance and industrial aesthetics. The exposed concrete ceiling, which contributed significantly to the industrial aesthetic, also housed integrated systems such as sprinklers, smoke detectors, and wireless equipment. Installing a suspended ceiling would not only compromise the visual appeal but also pose challenges in material shape and adaptability. Therefore, the decision was made to install absorbers on the walls instead. According to research [7] and results from [8], increasing the density of rockwool enhances low-frequency absorption (below 1000 Hz) while slightly reducing absorption in the mid-to-high frequencies. Given that 75% of the company's employees are female and the analyzed characteristic speech frequency range was identified at 100-500 Hz and 2000-4000Hz, high-density rockwool (140 kg/m³, 38 mm thick) was selected as the primary sound-absorbing material. With a Noise Reduction Coefficient (NRC) of 0.75, this material effectively addressed excessive reverberation.

To maintain the raw concrete aesthetic, upholstery material (C-0122) from manufacturer K was chosen to cover the rock wool. This fabric, with an airflow resistance of $R = 513 \text{ Pa s/m}$ (according to EN 29053), was selected to minimize its impact on the acoustic performance of the rockwool while preserving the desired visual consistency. A 10 mm air gap was left between the fabric and rockwool, functioning as an air damping layer to enhance low-frequency absorption. Figure 5 illustrates the design and the detail of the wall-mounted absorption structure, where L-section frames were used to secure the rockwool and fabric as an integrated acoustic system.

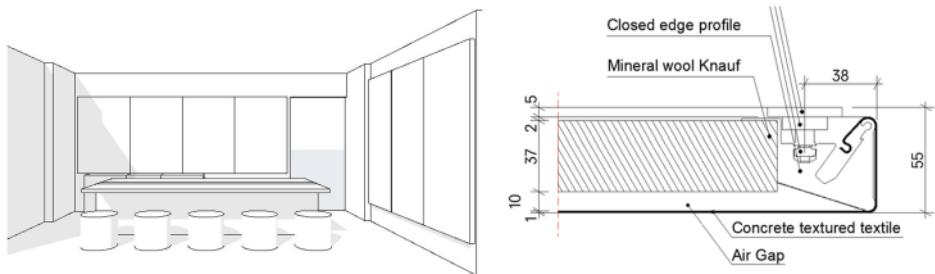


Figure 5: Design and details of absorber, (Source: Drawings by the Authors)

To prevent excessive sound reflection between parallel hard surfaces, absorbers were installed on both the north and south walls. Based on the room dimensions, initial reverberation time, target reverberation time, and material properties, the required usage of absorber was estimated to be approximately 10 to 15 square meters using the Sabine's equation. According to the final design, 12.6 square meters of absorber has been installed to optimize the acoustic environment. Equipment Relocation: Due to the long wavelength of low-frequency sound waves, reflections from the walls could occur. Users were advised to maintain a minimum 200 mm gap between the movable conference display screen and the walls to prevent excessive low-frequency reflections. Additionally, relocating the display screen to the western wall was recommended to avoid obstructing the newly installed absorptive panels.

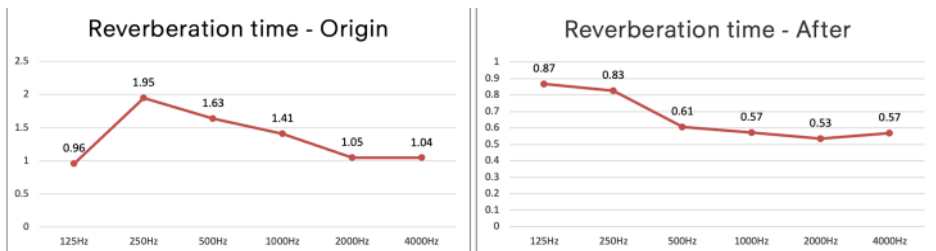


Figure 6: Reverberation time before construction (Source: Measurement by the Authors), **Figure 7:** Reverberation time after construction (Source: Measurement by the Authors)

Validation: After the completion of construction, reverberation time measurements were conducted again in the meeting room. Figure 6 and 7 present the contrast of reverberation time in octave bands, with an average reverberation time from originally 1.34 seconds to 0.66 seconds. On a subjective level, a follow-up visit was conducted one month later to gather user feedback. Post-occupancy subjective evaluation involving all eight employees revealed positive perceptions of the acoustic intervention. All participating employees (8/8, 100%) reported a noticeable improvement in the overall sound environment. Seven employees (7/8, 87.5%) perceived enhanced speech clarity during meetings. Five employees (5/8, 62.5%) indicated a perceived increase in meeting efficiency. Six employees (6/8, 75%) reported a reduction in fatigue-related pressure following extended meetings. Collectively, these findings suggest a subjectively favorable reception of the acoustic modifications across key dimensions of environmental quality, communication, efficiency, and post-meeting well-being. For the open space office, as there were no regular meetings or discussions held, movable acoustic partitions were implemented. These partitions effectively reduced echo while maintaining flexibility in space arrangement. In the showroom area, the exhibited clothing and luggage naturally provided good sound absorption. Additionally, the original flooring had already been carpeted, and the perceived acoustic environment was satisfactory. Therefore, no further acoustic modifications were deemed necessary.

DISCUSSION

This study provided an exploration of acoustic consideration during the adaptive reuse of industrial heritage buildings. A solution was proposed that balances industrial aesthetics with acoustic performance. Unlike normal cases that only focus on the overall average reverberation time, this research further developed the analysis by considering reverberation characteristics on frequency aspect. By utilizing a sandwich-type acoustic panel system composed of high-density rock wool, an air cavity damping layer, and low airflow resistance fabric (Figure 8), the reverberation time was optimized based on the frequency characteristics of human speech. This approach significantly improves auditory comfort. The methodology of this study encompassed preliminary data collection, on-site acoustic measurements, design and construction, and post-renovation validation, ensuring scientific perspectives and feasibility in actual. Both the objective reverberation comparison and subjective evaluations confirmed that the renovated space met the client's expectations in terms of acoustic performance. The findings of this study provide valuable acoustic optimization references for industrial heritage adaptive reuse.

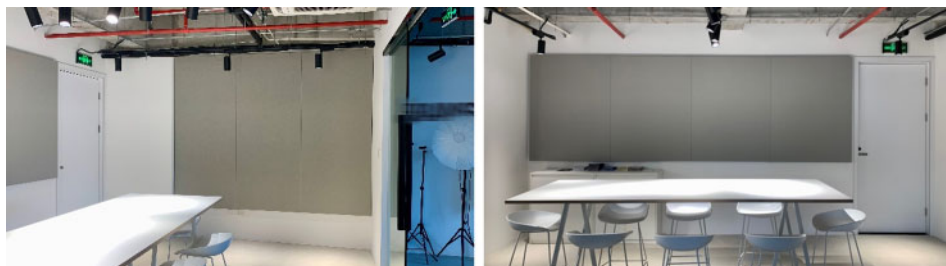


Figure 8: Photos after construction (Source: by the Authors)

Despite the positive outcomes, this study was limited to a single meeting room within Project R. Future research could expand the size and explore acoustic modifications for different functional spaces. A comparative analysis of various types of industrial heritage renovation projects could further validate the applicability of the acoustic strategies proposed in this study.

CONCLUSIONS

This study explores the acoustic considerations in the adaptive reuse of industrial heritage buildings, using Project R as a case study. A renovation plan that balances industrial aesthetics with acoustic performance was proposed. The findings indicate that a sandwich-structured acoustic panel composed of mineral wool, an air cavity, and fabric wrapping effectively reduces reverberation time. Unlike conventional approaches that rely on average reverberation time for overall control, this study refined the optimization process by sampling and analyzing the room's frequency characteristics. By adjusting the density of mineral wool and appropriate air cavities, reverberation time was optimized at the frequency-band level. The effectiveness of this approach was validated through both client feedback and comparative data analysis before and after renovation, demonstrating its practical applicability. This study provides valuable insights for future industrial heritage renovation projects, particularly in the precise control of reverberation time. The methodology could be further extended to other types of industrial buildings to enhance their acoustic environments while preserving their architectural aesthetics.

ACKNOWLEDGEMENTS

Hereby, the authors would give great thanks to Miss. Wanting Shen for essential help in the preliminary study and achieving period of this research.

REFERENCES

- [1] De Gregorio, Stefania, Mariangela De Vita, Pierluigi De Berardinis, Luis Palmero, and Alessandra Risdonne. 2020. "Designing the Sustainable Adaptive Reuse of Industrial Heritage to Enhance the Local Context." *Sustainability* 12, no. 21 (October): 9059.
- [2] Chen, J., B. Judd, and S. Hawken. 2016. "Adaptive Reuse of Industrial Heritage for Cultural Purposes in Beijing, Shanghai and Chongqing." *Structural Survey* 34, no. 4/5 (June): 331–350.
- [3] Vardopoulos, Ioannis. 2022. "Industrial Building Adaptive Reuse for Museums: Factors Affecting Visitors' Perceptions of the Sustainable Urban Development Potential." *Building and Environment* 222 (August): 109391.
- [4] Colorfull Design. 2020. "products page." Accessed March 31, 2025. http://www.colorfull-design.com/?post_type=products&page_id=15299.
- [5] Batteau, Dwight W. 1967. "The Role of the Pinna in Human Localization." *Proceedings of the Royal Society of London* 168, no. 1011 (August): 158–180.
- [6] Sabine, W. C., and M. D. Egan. 1994. "Collected Papers on Acoustics." *Journal of the Acoustical Society of America* 95, no. 6 (January): 3679-80.
- [7] Feng, Ai-jing, Wei, Qiang, and Zhang, Da-hai. 2017. "Theoretical Calculation and Performance Analysis of the Absorption Coefficient of Composite Materials." *Ship Science and Technology* 39, no. 2 (July): 65-69.
- [8] Golds, Bob. 2025. "Absorption Coefficients." Bob Golds. Last modified n.d. Accessed March 31, 2025. <https://www.bobgolds.com/AbsorptionCoefficients.htm>.