DOI: 10.61782/fa.2023.0583

ACOUSTIC CHALLENGES IN CONVERSION OF BUILDINGS TO RESIDENTIAL FUNCTION AS IDENTIFIED BY ARCHITECTS

Juraj Potočár[1,2] Veronika Blahunková[3] Vojtech Chmelík[2] Stanislav Unčík[2] Eva Vojteková[3] Monika Rychtáriková[1]

[1]KU Leuven, Department of Architecture, Campus Brussels and Ghent, Belgium.
[2]STU Bratislava, Department of Materials Engineering and Physics, Faculty of Civil Engineering, Slovakia.
[3]STU Bratislava, Department of Structures in Architecture and Engineering Buildings, Faculty of Architecture and Design, Slovakia.

ABSTRACT*

This article refers to challenges in guaranteeing acoustic comfort in buildings that undergo renovation processes, especially when conversion is performed from industrial or administrative buildings to dwellings. In recent years, the original industrial areas have been moving from the outskirts of the cities to the wider center. The buildings in them are increasingly sought after and many of them has been retrofitted to other function. When working with this type of objects, there are more possibilities of access - reconstruction, conversion to a new function, new additions to the original objects. In the further use of buildings built in the 19th and early 20th centuries, it is necessary to adapt the structures to current requirements that the original buildings no longer meet or don't meet requirements, because their function has changed. When working with such objects, architects need to solve many atypical problems compared to new construction.
This paper is based on a number of interviews with architects who have experience in the reconstruction and conversion of buildings in Slovakia. Information from interviews and surveys is extracted, analyzed, and summarized with a focus on sound insulation, materiality, and approaches used in the restoration process.

Keywords: *sound insulation, building retrofit, conversions of buildings, architecture, housing, circular materials*

1. INTRODUCTION

1.1 Historical context - Architecture

The world around us is constantly undergoing changes to which it is necessary to adapt. Changes in society also directly affect the architecture and use of buildings that no longer serve their purpose. In Slovakia, as well as elsewhere in Europe, many industrial and office buildings exist due to evolution in the past. Hungary, to which the territory of Slovakia belonged until 1918, was affected by the industrial revolution at the end of the 19th and the beginning of the 20th century[1]. Thanks to the railway connection, this industrialization largely affected Bratislava, which earned the nickname "Hungarian Manchester" due to the establishment of many factories[2]. However, this process still took place more slowly and to a lesser extent than in Western Europe or in the Western part of the Austro-Hungarian monarchy. After the establishment of Czechoslovakia, the prevailing opinion was that Slovakia would represent a kind of agricultural supplement to the industrially advanced Czech lands. In the 1930s, this thesis

***Corresponding author**: *juraj.potocar@kuleuven.be.*

was gradually abandoned and the demand to support the industrialization of Slovakia was heard more and more often. Political and economic changes after the restoration of the Czechoslovak Republic in 1945 strengthened the conviction about the need for the industrialization of Slovakia. This process took place throughout the first half of the 20th century, interrupted by crises, wars, and political upheavals.
After the February coup of 1948, economic policy and industrialization were led by the communist regime. The negative consequences of the industrial structure built after this period were multiplied after the collapse of the Soviet bloc, the loss of eastern markets, and the reduction of arms production at the turn of the 80s and 90s of the 20th century, which had a significant presence in Slovakia [1].
The conversion of industrial buildings to housing has its origins in New York in the late 1960s and early 1970s and gradually spread to Europe. It was the starting point for industrial renovation. The unique spaces and lofts attracted primarily artists and resulted in their own style of "Industrial Chic" - the deliberate display of structural elements or elements of former production. Today, that approach is being used aesthetically in all types of building conversions, not necessarily just in the case of factories and warehouses[3].
The result of the gradual transition to a market economy and the transition from the secondary to the tertiary sector (services, trade, transport...) was the gradual loss of the function of industrial areas and the creation of brownfields[4]. At the same time, as a result of this transition, a number of new office buildings and buildings were gradually created. However, changes in society are ongoing, and in the Western world, an increase in the vacancy rate of office buildings can be observed since the beginning of the 21st century. After the covid-19 pandemic in 2020, this process accelerated. US data for 2023 shows vacancy at record high[5]. The vacancy of office buildings leads to financial problems for the owners and social problems of the community[6]. A possible solution for both brownfields and office buildings is their adaptation to a new function, for example, housing. However, the problem can be not only a new function but also new requirements that the original buildings did not have to meet. The subject of the research is how not only investors but also architects approach these potentials, changes and challenges.

1.2 Historical context - Acoustics

To be able to understand to what extent sound insulation was taken into account in buildings built after the 2nd world war in Slovakia, a little overview on technical standards and regulation in this region is given: The first standard on acoustics in Czechoslovakia that specified requirements for noise values dates from 1953.This standard ČSN 1175 (from 1953) was later published without changes as ČSN 730531 in 1956[7]. It mentions the need to protect people's residences from noise. Noise values were in this normative regulation expressed in Loudness levels. (Note that the unit: phon was not the same as the phon-unit defined in current standards.) However, these were the predecessor of the (A, B or C) weighted sound pressure level[8]. The requirements for sound insulation (protection of building interior against noise), were described here mainly verbally, stating e.g. that building construction should be designed carefully, to reduce both, airborne noise as well as noise propagated by solid bodies, caused by footsteps: "Walls and ceilings should insulate the sound transmitted through the air, and the ceilings must also dampen the sound of footsteps. The sound propagated by solid bodies must be dampened mainly in industrial buildings and in buildings in which trade establishments are located." It is also mentioned, that rooms with frequently used water outlets and other strong sources of noise (kitchens, bathrooms, toilets, etc.) should not be located directly next to bedrooms, or at least pipes should not be placed in the bedroom walls. In multi-story buildings, bathrooms should be arranged next to each other and above each other as much as possible, and if, (in exceptional cases), noisy pipelines such as water and sewage, have to be laid in the walls of bedrooms or other rooms in which quiet is desired, the walls were supposed to be at least one brick thick so that the noise would be more attenuated. Pipelines may only be placed in partitions between apartments if there are rooms belonging to the apartment accessories (kitchens, bathrooms, toilets, storage rooms) on both sides of these partitions. The standard further stipulated, that all domestic installations such as heating, ventilation, water supply, and sewage must be adjusted, routed, and fixed in such a way that they are as quiet as possible and that they do not, as far as possible, transmit the noise caused by their use to other rooms. The standard formulated further the requirements for ventilation equipment which were supposed to be as quiet as possible and the noise at a distance of 1 m from the fans may not exceed 60 phons. In the case of the ceiling, the standard stated that an average sound attenuation of 48 dB should be guaranteed and footfall sound should not be higher than 85 phons. This standard was valid until September 30, 1961, when it was replaced by a new standard.
The recently valid standard in Slovakia STN 73 0532[9] sets the required sound insulation values for partitions between rooms in buildings and for sound insulation of building envelopes, including windows and doors by means of R_w and L_{nW} values. This standard also sets out principles for the design of residential and civil buildings from the point of view of building acoustics.

2. METHODOLOGY

As a research method, we chose a grounded theory. It is not research with exact data and numbers, but qualitative sociological research. Grounded theory methodology and methods (procedures) are one of the most important and widely used ways of carrying out qualitative research. It is a type of research where a certain theory (an explanation of what happens) emerges from information systematically collected during the research process. Researchers using grounded theory methods do not aim to find "the truth". Rather, they seek to conceptualize what emerges from the responses of study participants. When applying grounded theory methods, the researcher does not formulate hypotheses before collecting data, as is often the case in traditional research, otherwise, the hypotheses would be unsupported by the data. Hypotheses are supposed to emerge from the data. The goal of a researcher who uses grounded theory methods is to create concepts that explain the way people solve their major problems regardless of time and place. Concepts become the building blocks of the hypothesis, which subsequently become part of the theory. Grounded theory gives the researcher the freedom to create new concepts in explaining human behavior[10].
The advantages of using grounded theory include ecological validity, the discovery of new phenomena, and parsimony. Ecological validity refers to the extent to which research results accurately represent the real-world environment. Grounded theory research is often considered ecologically valid because the research is particularly close to the actual participants. Although the constructs in grounded theory are reasonably abstract, they are context-specific, detailed, and closely connected to the data. Because grounded theories are not tied to any pre-existing theory, grounded theories are often fresh and novel, and have the potential for new discoveries in science and other fields[11].
We conducted our sociological research among architects from Slovak architectural studios/offices, which were dedicated to the conversion of buildings in various forms and belong to important architects on the Slovak architectural scene. It was the architect Vladimír Hain and studios Kuklica Smerek architekti, GutGut, Architekti BKPŠ, Modulor Architecture and RB Architects. We have prepared a set of questions regarding the opinion on conversions, the attitude of investors, the use of materials, experiences with solving internal comfort during conversions from the point of view of acoustics, and also about experiences with the authorities, that deal with heritage and preservation of monuments.

3. RESULTS AND DISCUSSION

3.1 The attitude of architects toward conversions

At the very beginning of each interview, architects were asked to freely comment on the term conversion of buildings. Most of them simply referred to a new function of a building, for others the main association was a conversion of industrial heritage to other use. The common denominator for all could be the concept of change/retrofit. All the architects said that they like the concept of conversions, despite the complications and restrictions compared to new buildings. The common template for solving conversions consists in the initial determination of the parameters of the building, but also in trying to understand the operation, the essence of the building, and its genius loci.
All interviewed architects agreed on the fact, that there are a number of buildings in Slovakia that have been simply removed but could have been preserved and possibly adapted for a new function. Former industrial buildings in Bratislava were mentioned in particular - for example Istropolis, Cvernovka, Kablo, Gumon.

Figure 1. Interior of the industrial building “Cvernovka-part Pradiaren” (flax factory) before its retrofit to the office building

The architects also expressed the need for possible adaptation of the new building in the future. From the two principles - Raumplan and Plan Libre, Plan Libre seems more suitable from this point of view, as it allows free disposition in a skeleton or flexible construction.
Only in one case the opinion was opposite, where they argued that future developments are difficult to estimate.

Conversions of building stock to residential buildings were also positively perceived. The answer was repeated that for a certain type of public, such an offer is attractive even compared to new buildings. There are not many such realizations in Slovakia, so it will always find a clientele.

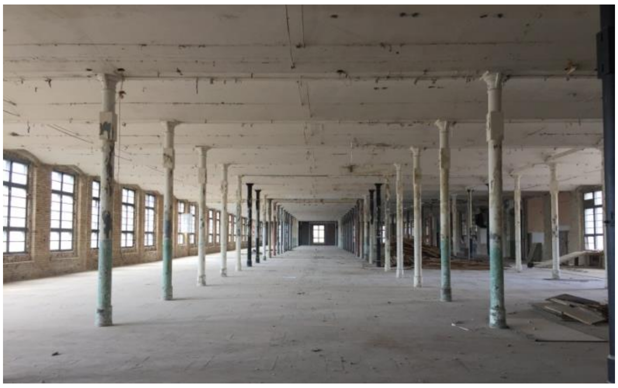

Figure 2. Interior of the industrial building "Cvernovka-part Pradiaren" (flax factory) before its retrofit to an office building

Figure 3. The exterior of the industrial building "Cvernovka-part Pradiaren" (flax factory) after its retrofit to an office building

3.2 Experience with investors in conversions

The consensus was found among architects, that investors are not always very keen on retrofitting buildings for other use. They concluded that the most successful implementations are created precisely when the investor is enlightened and addresses the architects themselves based on their previous work and approach. Often, however, since the acquisition of the property, they are set on the possibility of demolition of the whole building and designing completely new construction, for the purpose of the highest possible profit. In the eyes of many, conversion means an increase in complications and financial expenses. By one of them it has been even estimated, that only between 10-20% of investors in Slovakia are inclined to adaptive reuse of buildings and their conversions.

3.3 Choice of materials and autonomy of the architect

Based on the research interviews, it can be concluded that the architect decides on the used building materials in the first phase - during the project documentation. In the implementation of the project, the chosen materials only form a concept of the design to a certain extent. During this process, the contractor can have an influence in this respect. Architects typically carry out copyright supervision on their buildings to avoid changes in later stages. However, not all investors are willing to pay architects for this service. The author's supervision is in the contract by law in public contracts.

Some architects reported that the final decision on materials is sometimes driven by solving complex building details directly on the construction site. Conversions have one specific feature – one needs to be ready to deal with details not anticipated during the project. During the project realization, unexpected problems might appear, and one has to be able to solve them. Due to the new functions, it is necessary to use new constructions, which should interfere with the original ones as little as possible. The design of the building itself should be based on the principle of the logic of the original structure. The ambition is always to solve the problem so that later, the problem does not end up in the form of, for example, thermal bridges. Surprisingly, the interviewed architects did not spontaneously mention acoustic insulation.

When asked about the use of recycled materials, the approached architects associated this with reusing existing elements, such as old bricks or rubble from old bricks under the sidewalks, and they have not referred to building materials produced from recycled materials. They have mentioned that durable and high-quality elements (marble) can also be reused as part of facade cladding or interior design. Architect Rene Baranyai mentioned that in one conversion, metal elements were even melted down and reused in the form of sculptures by local sculptors. This was followed by more detailed questions about new, non-traditional materials and materials using, for example, recycled plastics. Roughly half of the respondents were not convinced in using materials such as concrete with plastic aggregate. They have expressed their concern on the recyclability of such lightweight material. It was mentioned that materials using natural materials such as hemp concrete, wood and clay are more acceptable for them.

Figure 4. Examples of recently developed materials based on recycled plastics [12,13]

3.4 Indoor comfort in buildings

Architects' consideration of acoustic and thermal comfort is based purely on valid standards. The research showed that architects cooperate with acousticians in projects with increased demands/requirements. Especially in the case of dwellings/apartments (Figures 5., 6.) and office buildings (Figures 1, 2, 3).
Also when room acoustics is concerned, architects collaborate with an acoustic consultant that will do the calculations and proposals. An acoustic model of the assessed room is sometimes also modeled, and the reverberation time and other acoustic parameters are calculated. The acoustic consultant typically also recommends materials to reach sufficient sound absorption.
One of the architects gave specific examples from practice when an acoustic consultant expert suggested a solution and materials to be used, but during the project realization, this was not implemented. Instead, a cheaper solution was chosen. Architects are often not able to check all details during building construction.
In architectural projects when conversions are involved, acoustic consultants are responsible for the design of floors and walls to meet the current standards. The original buildings are often poorly acoustically designed, especially those with wooden ceilings. Interviewed architects said that an acoustician is very necessary to eliminate all sound effects and that the mostly used acoustic solutions are found by mean of acoustic plaster, acoustic masonry, dividing walls and construction of acoustic ceilings.
Architect Rene Baranyai also outlined the importance of improving the acoustic conditions in public buildings. In particular, he described the acoustics standards in schools as "terrifying". Children and young people are more sensitive to noise, and many of these buildings were built to outdated standards. This has been also confirmed by several researchers [14, 15, 16]
This fact is also confirmed by Ecophon's research entitled "*A Sound Recovery for Schools"*, which is a follow-up to the latest OECD PISA study. Its aim was to find out how students perceive noise and poor physical infrastructure in schools. Research showed that over 25% of Slovak students experience noise in all or most lessons. At the same time, around 32% of students said that the school building they attend is hindered by its poor state of physical infrastructure, including poor room acoustics[17]. However acoustic comfort at schools is a topic of interest in many countries[18].
Rene Baranyai proposes phased modifications of schools, first, the corridors and other spaces with the accumulation of students would be modified with additional steps in order to improve the acoustic conditions. In the next phases, the classrooms would be modified.

Figure 5. Exterior of "Ružový mlyn" – conversion of the historic mill building to housing

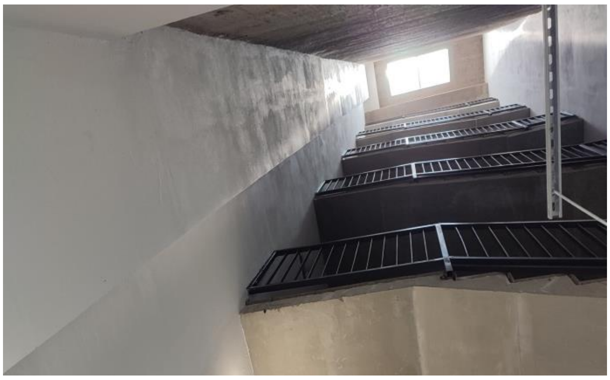

Figure 6. Interior of "Ružový mlyn" – new staircase construction and skylight

4. CONCLUSION

The conducted and in this article presented qualitative sociological research based on interviews with architects, performed during visits in their studios.
The aim of this type of research, so-called grounded theory, was to derive topics and define questions and hypotheses based on the ideas resulting from the answers.
Our research shows that all seven collectives of architects expressed a positive attitude towards building conversions, even at the cost of many complications. As for the acoustic solution, research shows that architects do not design it themselves, but leave it to acoustic consultants. The first problem can therefore arise when a project of building is too large, and it would be too expensive to pay an acoustic consultant who would check all constructions and mainly all building details. The education of architects in terms of acoustics should be considered one of the key elements in their education. One of the architects also mentioned, that databases of good practices and examples of good acoustic solutions in projects would help and he would definitely look in it.
On the other hand, many building details in architectural projects where retrofit/conversions are involved concern unique/individual problems resulting in very specific solutions of details.
It is our opinion that it would be very beneficial for architects to have more lessons on physics and acoustics so that they would gain certain intuition for their design.

5. ACKNOWLEDGMENTS

This project has received funding from the European Union's Horizon Europe research & innovation program under the HORIZON-MSCA-2021-DN-01 grant agreement No. 101072598 – "ActaReBuild". The authors would like to express their gratitude to all interviewed architects, for their availability to give an interview.

6. REFERENCES

[1] M. Bárnovský,"Industrializácia Slovenska a životné prostredie v období komunistického režimu", in *Acta OeconomicaPragensia*, pp 55-58, 2007.

[2] K. Kristiánová, K.Gécová, and E. Putrová, "Old industrial sites–conversion to parks: potential of Bratislava", in *Procedia engineering,* pp. 1858-1862, 2016.

[3] L. Jevremovic, M. Vasicand, M. Jordanovic, "Aesthetics of industrial architecture in the context of industrial buildings conversion", in *International Symposium*, pp. 85-86, 2012.

[4] H. Pavolová, et al., "Model of sustainable regional development with implementation of brownfield areas.", in *Entrepreneurship and Sustainability Issues*, pp.1089, 2019.

[5] A. Irwin-Hunt, " Out of office: US vacancy rates hit record high" in: *FDiIntelligence*,[online] , URL: <https://www.fdiintelligence.com/content/data-trends/out-of-office-us-vacancy-rates-hit-record-high-82348>, 2023.

[6] H. T. Remøy, T. J. Van der Voordt, "A new life: conversion of vacant office buildings into housing." in *Facilities*, pp. 219, 2007.

[7] ČSN 1175:1944, 1953 Building insulation - Part III: Sound insulation

[8] J. Schwarz: Historie a vývoj normových požadavků na zvukovou izolaci, abs-portal.cz, 2009.

[9] STN 73 0532:Acoustics. Rating of sound insulation in buildings and of building elements. Requirements

[10] Y. Zhuang, S. Zhijuan. "A Systematic Review of Grounded Theory Methodology: Re-Grounding in Weber.",in *The Journal of Applied Business and Economics*, pp. 107-134, 2019.

[11] K. Charmaz, "Grounded theory as an emergent method."*Handbook of emergent methods*, pp.155-164, 2008.

[12] Biskupicova, A., Ledererova, M., Uncik, S., Glorieux, C., Rychtarikova, M. Sound Absorption Properties of

Materials Based on Recycled Plastic Granule Mixtures, in *Slovak Journal of Civil Engineering, 29 (1)*, pp. 15-19, 2021.

[13] M. Ledererová, Z. Štefunková, V. Gregorová, D. Urbán, “The issue of plastic waste in the environment and its possible uses as a substitute for filler in lightweight concrete”,in *OP Conference Series: Materials Science and Engineering*, pp 1-7, 2019

[14] A. Astolfi, G. Minelli, G. E. Puglisi, “A basic protocol for the acoustic characterization of small and medium-sized classrooms”, in *Journal of the Acoustical Society of America*, 152 (3), pp. 1646 – 1659, 2022.

[15] L. Nijs, M. Rychtáriková, “Calculating the Optimum Reverberation Time and Absorption Coefficient for Good Speech Intelligibility in Classroom Design Using U50”, in *Acta Acustica united with Acustica 97(1)*, pp. 93-102, 2011.

[16] M. Jelínek, M. Rychtáriková, G. Vermeir, *Distribution of Background Noise in the Classroom and it’s Influence to Speech Intelligibility*. In Proceedings of the Internoise 2007, the 36th International Congress and Exposition on Noise Control Engineering. Istanbul ,Turkey, August 2007. ISBN: 978-16-056-0385-8.

[17] A. Petrencová, "Hluk a zlá priestorová akustika sú v slovenských školách bežné. Potvrdzujú to štúdie OECD aj prieskum Ecophonu" in:*Školské,*[online] , URL: <https://skolske.sk/clanok/59074/hluk-a-zla-priestorova-akustika-su-v-slovenskychskolach-bezne-potvrdzuju-to-studie-oecd-aj-prieskum-ecophonu>

[18] S. Dance, E. Ballestero, E.. Acoustics Of Classrooms, in *Frontiers for Young Minds*, pp 10, 804634. 2022.