Research Article

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Management strategies for refurbishment projects: A case study of an industrial heritage building

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Abstract: The use of renewable energy sources translates into increased environmental safety. The hydropower sector is in a phase of dynamic development. Despite the fact that the first references to the use of water for the production of electricity date back to the third century BC in Asia Minor, water management is not highly developed in Poland. Currently, its main resource is hydroelectric power plants, whose technical wear and tear often exceeds 50%. The implementation of renovation plans for power system facilities is necessary for the proper operation of buildings in order to reap maximum profits in hydropower. The article discusses two refurbishment strategies in industrial heritage buildings, using the example of the hydroelectric power plant in Sadow. A comparative analysis of the impact of the choice of renovated structural elements on the dynamics of the object's aging processes was carried out. The results of the analysis were used to identify key renovation needs and to develop a plan for necessary corrective actions.

Keywords: technical building condition, aging building changes, renovation project management, hydropower, sustainability

1 Introduction

One option for implementing the principle of sustainable development is the use of renewable energy sources (RES). To mitigate rapid climate change, it is essential to utilize potentially inexhaustible energy sources. The environmental aspect is a priority, particularly for future generations. The European Climate Law [1] and the European Green Deal [2] aim to achieve climate neutrality by 2050. Successfully implementing these objectives and transitioning to zero carbon for all Member States will mark a significant milestone for the world.

China is the pioneer in power generation, producing over one-fourth of the world's hydropower potential, approximately 390 GW. The next two countries in the hierarchy are Brazil (approximately 109.4 GW) and the United States (101.9 GW) [3]. In 2022, within the European Union (EU), the largest share of primary energy from RES came from solid biofuels at 40.3% [3]. Wind energy ranked second at 14.9%, followed by hydro energy at 9.8%. Regarding energy consumption by source, the average European in 2022 predominantly used natural gas (30.9%), followed by electricity (25.1%) and solid biomass (17.6%). In Poland, similar to the EU, the majority of energy production comes from solid biofuels, accounting for 64.5%. Hydropower ranks only seventh, after wind energy, liquid biofuels, solar energy, heat pumps, and biogas, contributing just 1.3%. In Polish households, the most commonly used energy sources are solid biomass (23.6%), natural gas (20.9%), hard coal (19.8%), district heating (17.5%), and electricity (12.4%) [4]. The statistical studies indicate that the development of the Polish hydropower sector is slower than European standards and has marginal importance. Poland's hydrological conditions do not support the rapid progress seen in countries like Sweden. The potential for advancing hydropower in Poland lies in maintaining and modernizing existing facilities and building new micro (up to 2 MW) and mini (up to 500 kW) hydropower plants while fully utilizing the country's river resources [5]. According to the Net Zero by 2050 analysis [6] conducted by the International Energy Agency, Poland is not alone in needing to accelerate hydropower development. It is estimated that, by 2050, 2,600 GW of energy should be generated worldwide using water, which would be double the current production.

The primary objective of private owners of industrial facilities is to maximize income from the sale of electricity

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generated by the power plant. They aim to shorten the return on their investment, often overlooking the historical significance of the building. For historic structures, all work must be conducted by qualified building professionals in consultation with the conservation officer and under the close supervision of the architect and contractor [7], which incurs additional costs. The scope of renovations should align with sustainability principles, incorporating energy optimization elements [8] based on a global warming potential analysis, while also preserving significant cultural and architectural values [9].

Regular inspection and maintenance primarily focus on technical equipment. Upgrades are mainly introduced to automate the generation process. However, the impacts of power plant operations – such as acoustic, landscape, and biological effects [10] – are not analyzed during the plant's life cycle. For economic reasons, refurbishments are often not performed, resulting in significant technical wear and tear on mini and micro hydro power plants. The expected lifetime of engineering structures is approximately twice as long as that of residential buildings, with a minimum lifespan of 100 years [11]. Therefore, the materials used must be durable and their application economically justified. Predicting the service life of building materials is particularly important due to the complex environmental operating conditions faced by industrial buildings situated over water [12]. Poor quality building materials, combined with unfavorable ground conditions – such as a high-water table, saturated soils, and uncompacted embankments – can be highly destructive to construction, especially for masonry structures [13]. In fact, determining the service life of an existing building is complicated by its multifaceted nature. A holistic approach must consider the physical, technical, functional, economic, political, and social dimensions of the issue. These criteria are referred to as obsolescence factors [14,15]. To ensure the reliability of building components, systematic measures must be implemented during the operational phase to facilitate proper maintenance. In cases of gross negligence in building maintenance, repairs or replacement of damaged components become necessary [16]. Loss of reliability leads to deterioration. Industrial buildings, due to their type and use, are classified in the lower risk group (2a) [17].

The assessment of wear and tear in facilities depends on renovation management. In cases of poor maintenance management, the linear method should be applied. For proper maintenance management, the linear method is also appropriate, while exemplary maintenance management warrants the use of the parabolic method [18]. For engineering structures, it is advisable to use the weighted technical wear and tear method, which allows for an individualized approach to each building element during site visits [19]. This marks the first step toward restoring the building's technical condition, a responsibility that falls to the building owner or manager [20]. The second step involves deciding whether to proceed with the renovation. This decision-making process is complex and poses a challenge for investors lacking construction knowledge. To aid in this decision-making, models are being developed worldwide that utilize fuzzy logic [21–23], a multi-criteria analytical hierarchy process [24], probabilistic approaches [25], building aging functions [26], or the Schroeder method [27]. The renovation must be a profitable investment. The most commonly used method for profitability analysis is net present value [28]. This analysis is complemented by a whole building life cycle assessment [29], which evaluates the environmental impact from the acquisition of raw materials for building material production, through the construction and operation processes, to demolition. Additionally, an economic analysis of life cycle costs is conducted over the entire life cycle [30,31].

Researchers are working to develop a method that supports decision-making in the planning of refurbishment projects, including those for historic buildings. However, this approach has yet to become operational. The existing methods are hindered by numerous limitations and imperfections, which significantly reduce their effectiveness. This is largely due to the complexity and breadth of the issues being addressed. Restoring a building to a good or at least average technical condition requires extensive structural and constructional measures. Additionally, the limited budgets of facility owners or managers pose another challenge; thus, when preparing the detailed scope of necessary work, it is crucial to prioritize tasks. It is uncommon for all renovation recommendations to be implemented because of funding shortages.

There is a clear need for further work to develop a holistic and universal approach to accurately manage renovation projects, especially in the context of industrial heritage sites. Drawing on an interdisciplinary approach, the authors introduced a novel research framework and proposed two alternative methods for planning renovation work, focusing on prioritizing interventions. The developed strategies set renovation priorities, taking into account key technical factors such as the degree of progressive degradation of building materials, the aging process of the building's load-bearing and non-load-bearing structure, and the impact of the facility's operation on the safety of the facility's use. The innovation of the authors' approach consists of the use of adaptive methods of technical condition assessment supported by building aging assessment functions, such as the $R_A(t)$ function, describing the set of progressive aging changes of individual building components occurring during the use of the building, and $R_M(t)$, representing the aging function of the renovated object. The use of these functions makes it possible to assess the dynamics of loss of performance over time, which is a milestone in predicting future renovation requirements. The application of these functions allows the assessment of the dynamics of performance loss over time, a milestone in predicting future renovation requirements. The proposed approach goes beyond the familiar framework of renovation engineering, as it integrates technical and analytical data into the decision-making process, enabling iterative adaptation of renovation strategies as a facility's condition changes, taking into account past renovation policies. This type of approach is particularly relevant to the preservation of industrial heritage buildings, which have unique structural and historical requirements. The developed method is applicable to both existing and emerging buildings, offering a versatile tool to support the sustainable management of building assets.

2 Investigation of the impact of renovated components on the technical condition of the building

The research carried out is based on the use of the $R_A(t)$ function [16], which describes the set of progressive aging changes of individual building components $R_i(t)$ occurring during the building's lifetime t:

$$R_A(t) = \sum a_i \ \exp\left[-\left(\frac{t}{T_i}\right)^2\right], \tag{1}$$

where $R_A(t)$ is the performance of the building during its lifetime t, T_i is the lifetime of the ith building element (years), a_i is the weighting factor of the ith building element, indicating the importance of the component being considered, and t is the useful life of the building (years).

The lifetime performance of a building involves assessing the degree of degradation of each individual building element, $R_i(t)$. This assessment determines the durability of the elements, expressed by the following formula:

$$R_i(t) = \exp\left[-\left(\frac{t}{T_{R_i}}\right)^2\right], \tag{2}$$

where T_{R_i} is the lifetime of the ith building element (years) and i is the ordinal number of the relevant building element.

The assessment of a building's aging process relies on integrating the durability of its individual components while considering various weighting factors. Literature studies have established these weights, which are essential for accurately evaluating a building's technical condition through a weighted wear-and-tear coefficient. A higher coefficient value signifies a greater impact of a component on the overall technical condition of the building. The weighted average method stands out for its accuracy, as it analyzes each building component in detail; therefore, we have decided to incorporate these coefficients into the method being developed. However, the weighted wear-and-tear method is the most time-consuming, as it requires thorough on-site inspections.

The operation of a building involves constant observation of its elements and ongoing maintenance. This includes carrying out renovation work to restore these elements to their desired technical condition. A comprehensive analysis of the building slated for renovation considers both its initial condition and the scope of the anticipated work. With this in mind, a function was developed to describe the aging process, specifically the change in performance over time.

The following equation, which represents the aging of the refurbished building $R_M(t)$ with n components, predicts the change in the building's performance:

$$R_M(t) = \begin{cases} \sum_{i=1}^{n-r} a_i \ \exp\left(-\left(\frac{t}{T}\right)^2\right) & \text{if } t \in (0,\ t_{pi}) \\ \sum_{i=1}^{r} a_i \ \exp\left(-\left(\frac{t - t_{pi}}{T_i}\right)^2\right) & \text{if } t \in (t_{pi}, T), \end{cases} \tag{3}$$

where r is the number of building elements renovated, n is the number of all building elements, t is the useful life of the building (years), t_{pi} is the deadline for carrying out repair work on the ith element (years), T_i is the lifetime of the ith element (years), T is the lifetime of the ith element (years), and a_i is the weighting factor of the ith building element indicates the importance of the object component under consideration.

The research analyzed literature data on the durability of individual titanium elements and the weighting factor (a_i), considering six overhaul planning strategies:

- Strategy 1: The renovation plans are limited to the nonstructural elements of the building and are carried out in the 80th year after the building is put into use, in accordance with its estimated lifespan.

- Strategy 2: The renovation plans focus solely on the load-bearing elements of the building, essential for meeting the load-bearing limit state condition. Renovation occurs in the 80th year after the building is put into use.
- Strategy 3: Priorities in the renovation schedule are determined by assessing the technical condition of the non-structural elements. The selection of elements for refurbishment is based on their degree of wear and tear and their impact on the overall condition of the building.
- Strategy 4: Priorities in the renovation schedule are based on assessing the technical condition of the building's structural elements. The selection of elements for renovation is determined by their degree of wear and tear and their impact on the overall condition of the building.
- Strategy 5: No renovation works are planned during the 100-year period for which the building was designed.
- Strategy 6: This strategy considers the renovation of both structural and non-structural elements in accordance with their service life.

A model was developed to describe the aging process of a building constructed with traditional technology, reflecting changes in performance over the years of use. The model's results are presented graphically in Figure 1.

Performance changes were assessed over a period of 0–100 years, a timeframe chosen based on the design life of engineering buildings. The choice of this scope allows for a comprehensive and multifaceted look at the dynamics of the aging processes of structures, both in the context of their actual service history and theoretical renovation management scenarios. A key assumption of the analysis was to take into account the fact that the building is now 80 years old and that the renovation policy implemented in the past has shaped its current technical condition. A renovation strategy cannot be implemented retrospectively, but simulation modeling of hypothetical renovation scenarios allows assessment of the potential effects of alternative approaches to facility management. As a result, the study includes both a retrospective assessment of the effectiveness of past actions and a predictive analysis of the impact of different renovation strategies on the condition of the building in its 100th year of use. The theoretical analyses carried out also have important practical implications. First, they make it possible to determine the impact of variable renovation decisions on the long-term durability of a building. Second, the model provides an understanding of what actions would have to be taken in the past to achieve the optimal performance of the building today. Third, the proposed approach provides a broad spectrum of applications – from existing buildings, for which optimal renovation policies need to be developed, to buildings yet to be designed, where the model can support design decisions on the durability and timing of future maintenance activities.

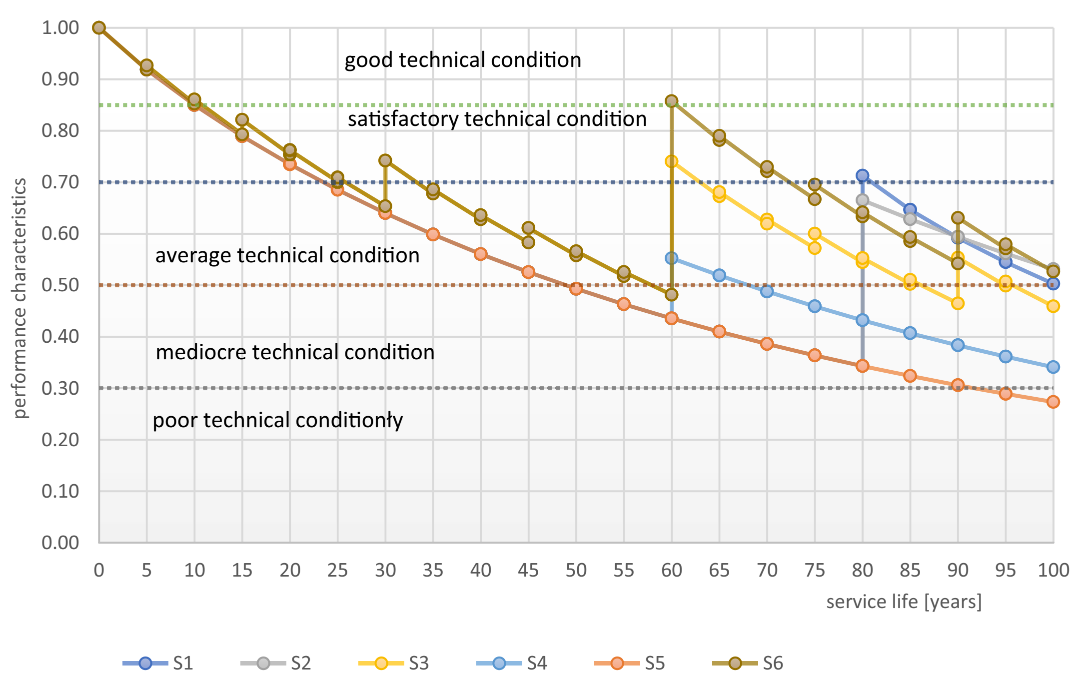

Figure 1: Aging functions of buildings for refurbishment strategies S1–S6.

The integration of the retrospective and prospective approaches is innovative and highlights the fullness of the analysis, allowing universal application of the developed model. As a result, the tool supports both the ongoing management of buildings and strategic decisions for engineering facilities at different stages of their life cycle. Such versatility makes the model particularly valuable in the context of managing the sustainability of building infrastructure.

The results indicate that for industrial buildings at their 100th year of use, two equivalent strategies are the most favorable: S2, which involves renovating only the structural elements in the 80th year, leading to a significant improvement in the aging function with a relatively low decline, and S6, which entails ongoing renovation efforts in line with the lifespan of the building components, resulting in a substantial increase in the aging function.

3 Case study: Small hydropower plant (SHP)

An analysis was conducted to select an appropriate refurbishment strategy for the SHP in Sadow. This strategy is essential for developing a refurbishment work schedule that prioritizes necessary tasks in response to ongoing aging changes in the building. The SHP is an industrial heritage site that harnesses river water for electricity production and includes storage rooms for water mechanism components and operational tools. It was constructed after World War II, around 1945, to replace a historical water mill (Figure 2).

The analyzed building is located on the outskirts of the village, at the site of a former historic watermill. The power station is located on the municipal road of the Cybinka-Rzepin route, next to the bridge of the Pliszka River. The building is located on a plot of land marked with the property register number 67/2 with an area of approximately 5.83 a (Figure 3).

The building is situated on a slope, constructed using traditional technology on a plan of a rectangle. It is an object with a longitudinal structural system, two-storey, including one underground storey. It has two entrances from the north side of the world.

The main room of the power station houses three water turbines, two power generators, a water cleaner, electrical components, and a storehouse for tools needed to maintain the machinery. Structurally, the typically industrial part of the building differs from the rest. The walls on the west and east sides are of steel construction with a straight or trapezoidal sheet metal finish on the outside. On the south (river side), there is a masonry wall at the basement level and a steel-framed wall above. The ceiling is of concrete slab. The roof is mono-pitched, covered with trapezoidal sheet metal, glazed in places.

The remainder of the building has a stone foundation on which the load-bearing walls of cement-lime mortared

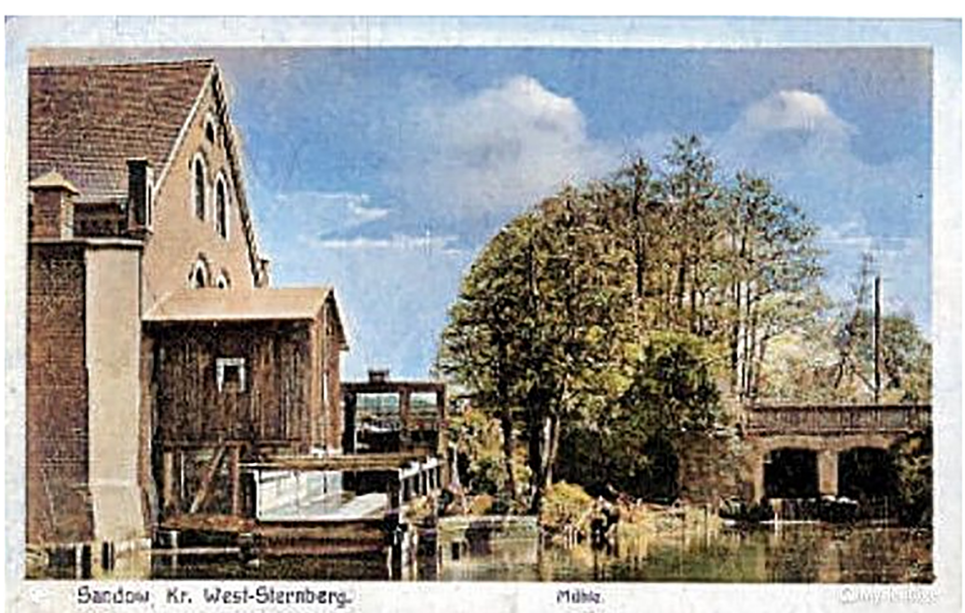

Figure 2: The old watermill before demolition (from the archives of Sadow residents).

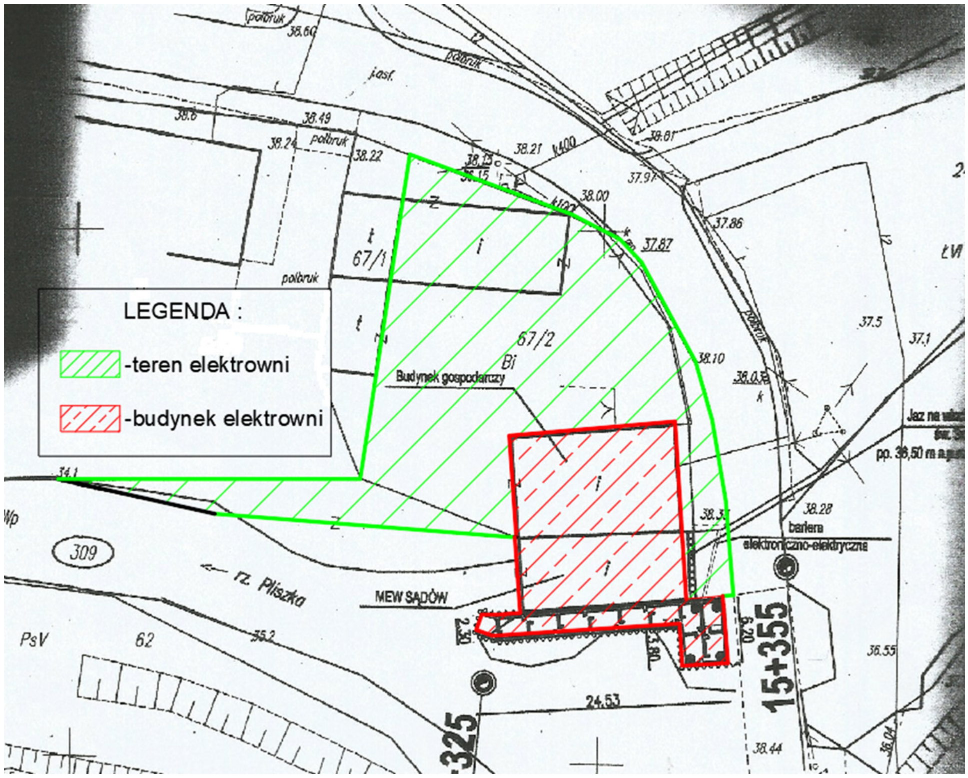

Figure 3: Site plan of the power station.

cinder blocks are erected. The partition walls are made of solid brick. The ceiling over the ground floor is wooden, covered with dried reed, and finished with traditional plaster. Until 2014, the gable roof covering was made of eternit boards with harmful asbestos fibers. Today, the double-joined, collar-and-beam roof structure is covered with red trapezoidal metal sheets.

The rooms on the ground floor and the walls in the basement are covered with cement-lime render painted white. Outside the building, the masonry load-bearing walls are plastered with cement mortar and the sheet metal walls are repainted with a grey corrosion protection coating.

An assessment of the technical condition of all building elements was carried out using a visual method based on observations from a site visit [32].

The building sits on a stone foundation with an average width of 80.00 cm and a height of 180.00 cm. A layer of solid bricks with cement mortar is built on the footings. There is no horizontal or vertical insulation.

It is planned to expose and dry out the foundation walls using temporary trenches. Vertical insulation is to be carried out using a polymer compound, protected from mechanical damage by a bucket film, and horizontal insulation of the walls using an injection method to prevent capillary rising of water through the walls.

The basement walls are made of cinder blocks with a total thickness of approximately 30.00 cm. Cracks and fissures are visible on them. There is local dampness of the walls in the corners of the building, so it is recommended that the plaster be stripped and the repaired surfaces be dried and cleaned. Defects in the cement-lime plaster should be replenished, and the top layer of the walls should be covered twice with gypsum plaster.

In the 30.00 cm thick load-bearing walls, masonry made of cinder blocks, aerated concrete blocks, or solid bricks, respectively, the repair of numerous vertical cracks with polymer-cement repair mortar is envisaged. In the north-east corner of the building, a steel anchor is to be used due to uneven ground settlement. The deviations of the load-bearing walls from the vertical are up to 3.00 cm (Figure 4).

The partition walls are made of solid bricks in cement-lime mortar with a total thickness of 16.00–19.00 cm, including traditional plaster on both sides. The right angles of the internal partitions are maintained. The wall cladding is locally detached due to the high humidity in the building.

The timber collar beam roof truss with two joist walls is in good condition, as can be seen in Figure 5. There are

Figure 4: View of the north and west walls.

no visible deflections, cracks, or cavities. The roof truss elements are not waterproofed.

The roof is primarily double-pitched, covered with trapezoidal sheet metal. A roof membrane is installed between the wooden structure and the roof slope, ensuring no absorption. On the southwest side, the single-pitched roof slope consists of glass elements (as in Figure 6) supported by steel structures. A glass insulation layer was used

Figure 5: View of the roof structure.

to lower the plate. Automatic replacements of the glass occur with new elements that have improved thermal and acoustic properties.

On the ground floor, a concrete slab has been poured onto the monolithic ceiling, which exhibits numerous visible gaps and unevenness. To improve its technical condition, a self-leveling compound should be applied after thoroughly preparing the substrate by cleaning and degreasing the surface, filling large gaps with repair mortar, and priming to enhance adhesion.

The basement features a monolithic ceiling supported by ribs spaced every 130 cm, with a ceiling slab height of 18 cm. Local concrete gaps are evident and should be filled with repair mortar. Additionally, part of the ceiling above the basement is finished with gypsum plaster.

The ceiling above the ground floor is wooden, covered with reed, and finished with traditional plaster. Damaged, rotten, and moldy boards have been removed from sections of the ceiling. The plaster shows signs of scorching and cracking. Due to the potential risk to human life and health, it is recommended to replace elements affected by biological corrosion.

The chimney is constructed from solid bricks and cement mortar, measuring 78 cm × 65 cm. Cracks in the plaster are visible near the central heating boiler. The flue gas riser is intact, with no brown efflorescence present on the walls.

The window joinery is wooden and poorly maintained, as evidenced by cracks and peeling paint in several areas. There are significant leaks, thermal bridges, and issues with opening and closing individual windows, and window sills have not been installed. It is recommended to replace the window joinery with new units.

Steel door frames have been installed internally, showing local scratches due to the absence of lintels and inadequate reinforcement cover. The door leaves are wooden and poorly maintained, with four leaves missing. The internal door joinery should be entirely replaced.

Gutters have been installed only on the north side of the building. The slope of the gutter strip is incorrect, resulting in observed water pooling. There are no downpipes to drain rainwater from the roof surface. A dedicated roof drainage system should be selected, and the existing gutter should be unclogged and the slopes corrected.

The internal wall cladding consists of cement-lime plaster, varying in thickness from 2 to 4 cm. Minor scratches and plaster defects are visible in several areas. Cracks are present in the building's corners and around the window and door joinery. There is no plaster work on the window frames. Cracks and scratches should be repaired, and damaged or scorched plaster should be chipped off, thoroughly cleaned, and degreased before filling the defects with additional reinforcement using a dedicated mesh.

The external plaster is made from cement-lime mortar, with an applied layer thickness reaching 5 cm. Areas where doorways used to exist are missing cladding. A large section of scorched plaster is visible on the north side of the building. The elevation is dirty, with numerous shrinkage cracks in the plaster and no insulation present. The scorched plaster should be removed, and the repaired areas must be thoroughly cleaned, primed, and finished with a new layer of plaster made from cement-lime mortar.

The electrical and plumbing installations are functional, but there is no central heating system.

An assessment of the building's technical condition was conducted, and the results are shown in Table 1.

During the site inspection, a detailed visual inspection was carried out of all components of the hydroelectric power station at Sadow. The technical condition of the

Figure 6: View of the building from the south.

Table 1: The degree of wear of the technical condition of the components of the hydroelectric power plant in Sadow

Lp.	Building components	Type of component K – structural; N – non-structural	Degree of wear of technical condition (%)
1	Stone and brick foundations	K	20
2	Cinder block walls	K	30
3	Masonry partition walls	N	30
4	Ceilings	K	30
5	Wooden above the ground floor and reinforced concrete above the basement)	K	5
6	Roof truss	N	70
7	Roof covering	N	100
8	Trapezoidal sheet metal and glass panels	N	40
9	Gutters and downpipes made of galvanized steel sheet	N	50
10	Interior plasters	N	80
11	Exterior plasters	N	75
12	Window joinery	N	55
13	Door joinery	N	85
14	Glazing	N	70
15	Wooden floors (softwood)	N	60
16	Paint coatings for walls and ceilings	N	10
17	Oil paint coatings for joinery	N	15
18	Chimney	N	15
19	Water and sewage pipes (galvanized steel)	N	20
20	Water and sewage fittings	N	20

building was determined to be mediocre. Structural components, which account for 20% of all building components, are in satisfactory condition. Their average degree of technical wear is 21.25%. Installations are in good or satisfactory condition. Non-structural elements of the building, including guttering, roofing, window and door frames, and paint coatings, show the greatest degree of technical deterioration. They account for 80% of all building elements, and their average degree of technical wear is 49.69%.

The building is operated as intended.

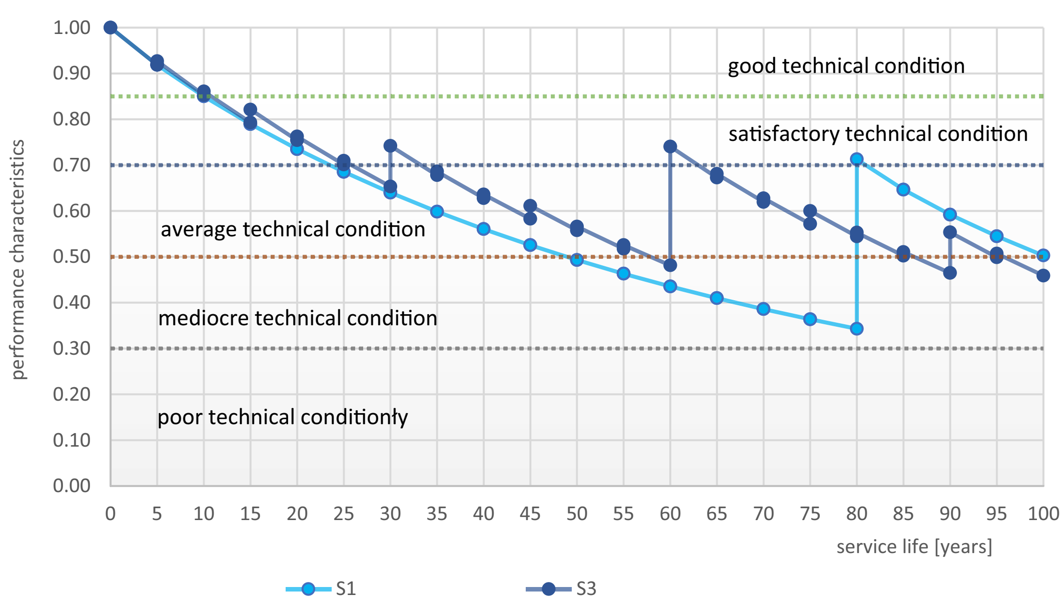

Figure 7: Aging functions of buildings for refurbishment strategies S1–S3.

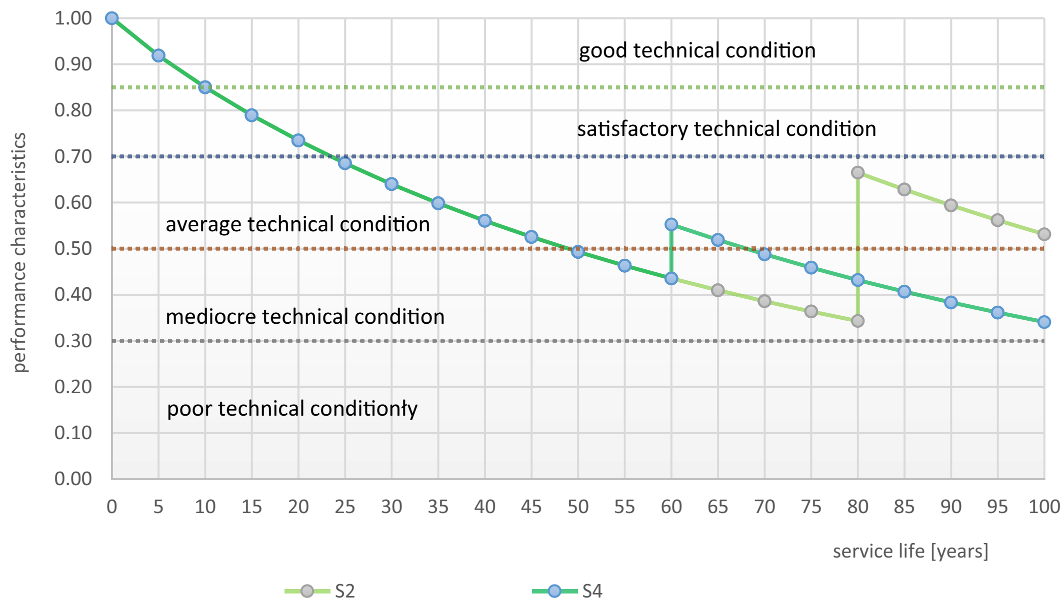

Figure 8: Aging functions of buildings for refurbishment strategies S2–S4.

4 Analysis of results

The method described in Section 2 was applied to the 80-year-old small hydroelectric power station in Sadow, located on the Pliszka River, built to replace a historic mill. It is based on a comparison of up to 6 refurbishment strategies. The aging function diagrams for strategies S1 and S3 (Figure 7), S2 and S4 (Figure 8), and S5 and S6 (Figure 9) are presented below.

The renovation strategies S1 and S3 refer to renovating only the non-structural elements of the building. The light blue graph illustrates a strategy based on the assumption that no renovation work occurs until the 80th year of the building's use. In that year, renovations are performed on all non-load-bearing components, regardless of their condition. In this case, these components are primarily in mediocre to poor condition. The dark blue graph depicts the performance changes of non-structural components overhauled

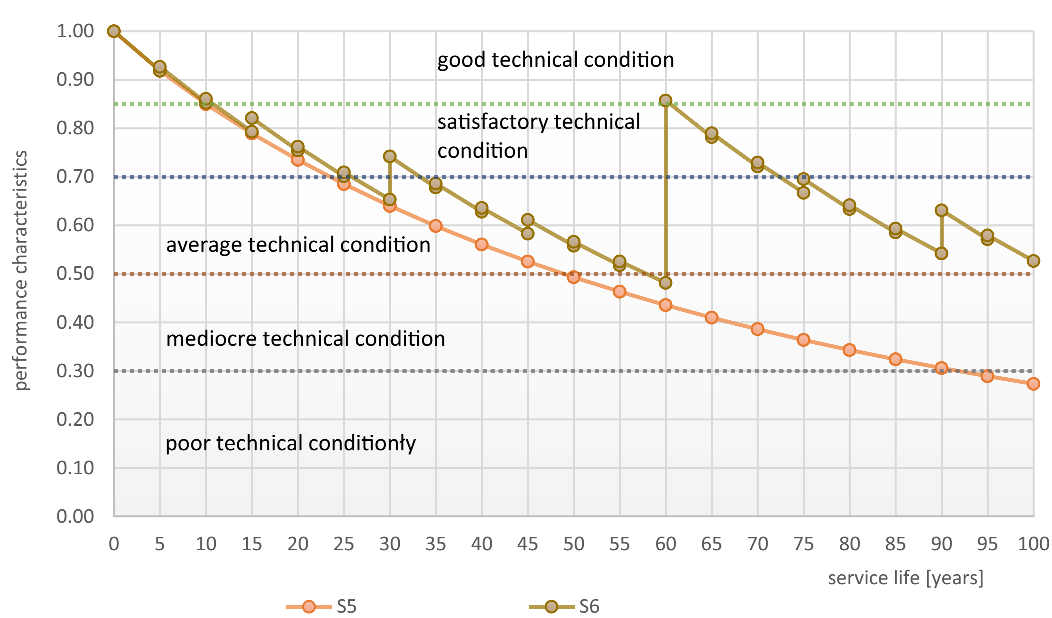

Figure 9: Aging functions of buildings for refurbishment strategies S5–S6.

Table 2: Capacity of the SHP at Sadow in the 100th year of operation of the facility for strategies S1–S6, respectively

Strategy	Components considered in the strategy (K – structural, N – non-structural)	Value of the performance characteristics in the 100th year of use	Technical condition of the building
S1	N	0.503	Average
S2	**K**	**0.531**	**Average**
S3	N	0.459	Mediocre
S4	K	0.341	Mediocre
S5	**N + K**	**0.273**	**Poor**
S6	N + K	0.527	Average

according to their expiry dates. By the 100th year of use, a building undergoing refurbishment under strategy S1 (with a performance rating of 0.50) or S3 (with a performance rating of 0.46) will still be in mediocre condition.

The renovation strategies S2 and S4 focus solely on the load-bearing elements of the building. The light green graph illustrates the scenario in which no renovation work is performed until the 80th year of the building's use. At that point, the building's structure – comprising foundations, walls, ceilings, and roof trusses – is renovated, regardless of its wear and tear. In this scenario, these components are in mediocre condition. Nonetheless, renovating them 80 years after the building's initial use restores it to an average condition, yielding a performance rating of 0.53 that lasts until the 100th year. The dark green graph represents renovation strategies aligned with the service life of the elements. By the hundredth year of use, strategy S2 results in the building being in medium condition, while strategy S4 places it in mediocre condition, with service properties rated at 0.34.

Figure 9 illustrates the two extreme renovation strategies, S5 and S6. The red graph depicts the performance change of the building that is not subject to refurbishment, following assumption S5. By the 100th year of use, the building is in poor condition, with performance characteristics at 0.27. In contrast, the orange chart represents exemplary maintenance throughout the facility's lifetime, with a schedule for repairs based on the lifetimes of various components (strategy S6). The crucial year for repairs is the 60th year of operation. In the 100th year, a building employing strategy S6 achieves a performance rating of 0.539.

Table 2 presents the performance values for the building in its 100th year of use under each strategy.

In the long term, the most favorable strategy was S2, which involved refurbishing all components of the support structure of the hydroelectric power station in Sadow. The second most suitable strategy is S6, which entails ongoing maintenance of the structure. The least favorable strategy is S5, which involves no refurbishment.

5 Summary and conclusions

The owner or manager of a building is obligated to maintain it in good repair, which limits wear and tear to no more than 50%. To fulfill this legal obligation, and considering the often-limited financial resources, it is essential to identify the most urgent renovation needs. A comparative analysis revealed that the choice of building elements to be repaired significantly impacts the building's performance, with the type and timing of repairs being crucial. The load-bearing structure of a building plays a vital role in this context. Regular repairs throughout the entire lifecycle of the building (up to 100 years) in accordance with the lifespan of individual components, as outlined in strategy S6, are less effective than a one-time repair of only the load-bearing components in the 80th year of use, as proposed in strategy S2. Strategies S2 and S6 are the most desirable due to the highest values of performance in the 100th year of use of the building. When carrying out the renovation policy according to strategy S1, the technical condition of the building in the year under consideration is average, which is acceptable. The implementation of strategies S3 and S4, which take into account the renovation of non-structural and structural elements, respectively, in the case under consideration is unjustified, because in the hundredth year of use, the performance characteristics fall below the value of 0.50, so the technical condition will be mediocre. It is unacceptable not to implement renovation plans as in the S5 strategy, because we will lead to a poor technical condition of the building.

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Data availability statement: The data supporting the findings of this study include renovation planning strategies and related visualizations (graphs). These data are provided in the manuscript in the form of charts, tables and supplementary figures. No additional data are available outside the manuscript. Additional Information: The original method can be applied to solve problems occurring in practice. This manuscript has not been published and is not under consideration for publication elsewhere. I have no conflicts of interest to disclose. Publication costs will be covered by the University of Zielona Góra.

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