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Material Conservation in Adaptive Reuse: Its Role and Relationship to Sustainability

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Abstract

Adaptive reuse is increasingly becoming a mainstream approach in architecture as a way to preserve cultural heritage, reduce carbon emissions, minimize material use, and promote sustainability in multiple ways. Within adaptive reuse, material conservation is an important but less-explored aspect that supports sustainability. This work examines the relationship between adaptive reuse and material preservation, emphasizing how maintaining original building materials benefits heritage continuity and sustainability. By reviewing published literature and analyzing various local and international case studies, the study considers the strategies, strengths, and challenges of material preservation in adaptive reuse projects. It highlights the substantial environmental benefits of resource efficiency, waste reduction, and energy savings embedded in materials. Furthermore, the research explores the ecological, economic, and cultural impacts of material conservation strategies on the long-term sustainability of adaptive reuse efforts. The paper underscores the essential role of material conservation as a strategic approach in adaptive reuse, aiming to enhance understanding and reinforce the importance of preserving original materials.

1. INTRODUCTION

The most important aspect of heritage conservation is adaptive reuse, which replaces new construction and demolition with reusing existing buildings for different purposes. Adaptive reuse is "any work undertaken on a building above maintenance that attempts to modify its capacity, function or performance," as noted by Douglas [1]. This approach not only preserves architectural heritage but also plays a vital role in environmental sustainability by extending the lifecycle of built assets and conserving the embodied energy of existing materials [2].

Adaptive reuse has been recognized worldwide as a way to reduce energy use, cut down on waste, and support urban renewal amid growing environmental issues [3]. Organizations like Australia's ICOMOS (2013) and the European Commission (2014) now officially see adaptive reuse as a vital part of sustainable development policies, connecting it with cultural preservation and resource conservation. However, even though material preservation is a key part of adaptive reuse, it has often been overlooked.

Gorgolewski acknowledges that using traditional building materials reduces the environmental impact of construction activities while maintaining the aesthetic and historic qualities of buildings [4]. By reusing and recycling materials like brick, stone, and wood, projects can avoid energy-intensive processes involved in creating new materials, thus supporting higher carbon reduction goals [5]. Although this is possible, current literature does not adequately explore the relationship between adaptive reuse, sustainability, and material preservation. While adaptive reuse is often valued for its urban and cultural significance, Velthuis and Spennemann point out that there is no systematic framework to include material preservation in sustainability assessments [6]. Plevoets and Van Cleempoel also argue that material conservation should be regarded as a key environmental approach to sustainable architecture, not

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just a heritage-related activity [7]. Recent research further highlights the various ways in which material conservation contributes to environmental sustainability within adaptive reuse projects.

Mohamed et al. prescribe a framework that covers the three basic dimensions of environmental, economic, and social aspects for sustainability evaluation in adaptive reuse projects [8]. In their study assessing the environmental, economic, and social factors of adaptive reuse, they stated that low carbon emissions, especially through material conservation, are vital to environmental sustainability. Abdulameer and Abbas highlighted that decisions on adaptive reuse increasingly prioritize sustainability, but economic viability often remains the decisive factor; therefore, successful heritage building reuse requires preserving original materials and character, implementing minimal yet compatible interventions, securing government support and funding, and encouraging community involvement to achieve environmental, social, and economic sustainability outcomes [9].

Similarly, Wei et al. emphasize that using original building materials in China's industrial heritage projects maximizes the overall environmental efficiency of the renovated structures while also reducing their carbon footprint. This approach ensures that adaptive reuse techniques meet both ecological and cultural goals, aligning with larger sustainability frameworks that promote minimal interference and maximum preservation of historical fabric [10]. Additionally, adaptive reuse practices in Seoul's urban regeneration areas have demonstrated that conserving materials not only promotes environmental sustainability but also supports social continuity by maintaining residents' connections and collective memories associated with heritage apartment buildings [11].

These findings show that material conservation practices in adaptive reuse projects are not just aesthetic or cultural choices but should also be a core strategy for achieving sustainability goals. While the importance of adaptive reuse in sustainable development is well known, this article aims to highlight the often-overlooked fact that conserving materials is especially crucial for sustainability in adaptive reuse. It examines how preserving original building materials advances environmental objectives beyond just aesthetics and history. This includes how waste reduction, lower carbon emissions, and retained embodied energy benefit the environment. The study is both theoretical and practical: it explores key scholarly frameworks and evaluates four case studies—Gasometer City (Vienna), Tate Modern (London), Salt Galata (Istanbul), and CerModern (Ankara)—to demonstrate different approaches to material conservation in adaptive reuse projects.

The article is organized around the following research questions to direct the investigation:

- How does material conservation help adaptive reuse projects achieve their sustainability goals?
- What are the potential economic, cultural, and environmental advantages of reusing original building materials?
- What can be learned from a few chosen adaptive reuse case studies, and how do they represent material conservation strategies?

By framing the investigation around these questions, the study explores the relationship between material conservation and sustainability outcomes, contributing to an area that remains underexplored in adaptive reuse literature. These questions help establish the analytical framework of the article and ensure alignment between theory, method, and findings.

This article aims to contribute to the sustainable architecture debate by highlighting the importance of material conservation in adaptive reuse processes. In published literature, material conservation is mainly discussed within the context of cultural heritage and is not sufficiently evaluated as an environmental strategy [6]. However, Gorgolewski states that preserving the embodied energy in buildings and avoiding environmental costs associated with the production and transportation of new materials are vital for sustainability goals [4]. Similarly, Powter and Ross also stress the potential of reusing materials like brick, stone, and wood to lower carbon emissions [5].

Recent studies have further advanced this approach, demonstrating that conserving materials directly influences the sustainability performance of adaptive reuse projects. Guidetti and Ferrara showed that reusing building materials in adaptive reuse can significantly cut life-cycle carbon emissions, thereby improving the overall environmental performance of buildings [12]; Conejos et al. highlighted that adaptive reuse achieves better sustainability results when material conservation strategies are incorporated from the earliest design stages [13].

This study aims to provide a reasoning that is not limited to cultural or aesthetic considerations but recognizes material conservation as part of the environmental bottom line. This helps raise the importance of the environmental aspect of adaptive reuse and is crucial for resource efficiency, reducing carbon footprints, and fostering long-term responsibility within the built environment.

Additionally, the article will help address methodological shortcomings in this field by providing a comprehensive approach to assessing material conservation practices using sustainability criteria. This will inspire new design strategies focused on material conservation and encourage their integration into environmental and cultural sustainability goals. While adaptive reuse is widely discussed in terms of cultural and urban significance, this study specifically highlights material conservation as a critical yet often overlooked strategy for achieving sustainability outcomes in adaptive reuse projects.

2. METHOD

This article's qualitative research methodology combines a comprehensive literature review with a comparative analysis of selected adaptive reuse case studies. The goal is to examine how material conservation techniques are applied and how they support environmental and economic sustainability across various architectural and cultural settings.

Table 1. *Methodological Framework*

Phase	Description	Purpose
Literature Review	Examination of academic literature to define key concepts, theories, and research gaps	To build a conceptual base and guide case selection criteria
Case Study Selection	Choosing diverse international and local examples based on relevance and reuse potential	To ensure variety in scale, typology, and sustainability Orientation
Data Collection & Analysis	Gathering data from ublications, reports, and documents on material strategies in reuse projects	To understand real-world material conservation strategies and their applications
Comparative Evaluation	Cross-case analysis of environmental, economic, and cultural outcomes of material reuse	To identify patterns, context specific approaches, and effectiveness of conservation efforts

The four successive phases of the methodological framework are as follows:

I. **Literature Review:** A critical analysis of research literature was conducted to identify key concepts, theoretical foundations, and gaps in research on adaptive reuse and material preservation. This step established the conceptual framework of the article and guided the selection of cases to include.

II. **Case Study Selection:** The combination of international and local case studies was selected based on their relevance to the research issue. The selection criteria included project sustainability goals, size, type, and the level of material reuse. The chosen cases represent a variety of historical, architectural, and urban contexts.

III. **Data Collection and Analysis:** Various sources such as institutional records, peer-reviewed articles, sustainability reports, and building documentation were accessed to review each case. This stage aimed to identify specific material conservation techniques like the reuse of steel, brick, stone, and wood, and evaluate how effectively they were being implemented in real situations.

IV. **Comparative Evaluation:** A cross-case comparison of material conservation strategies' cultural, economic, and environmental impacts was conducted. This stage identified similarities, context-dependent solutions, and the extent to which they aligned with sustainability goals. Using this methodological framework, the article aims to provide a comprehensive understanding of how material conservation contributes to adaptive reuse initiatives that both preserve cultural heritage and promote sustainability.

3. LITERATURE REVIEW

The last 20 years have experienced a significant increase in academic interest in adaptive reuse, mainly driven by growing concerns about material shortages, urban regeneration challenges, and environmental deterioration. The importance of adaptive reuse in advancing sustainable architecture is increasingly acknowledged. Adaptive reuse is a vital part of sustainability because it extends the lifespan of existing structures, reduces material waste, conserves embodied energy, and lowers the need for new construction [1] [2].

Current research explored the economic and environmental benefits of recycling old materials through adaptive reuse schemes from a sustainability perspective. It is well known that adaptive reuse can reduce carbon emissions, prevent construction waste, and save the embodied energy of materials. According to Langston et al. and Yung & Chan, adaptive reuse offers advantages such as lowering the environmental footprint and maintaining historical significance [3][14]. Additionally, it is cost-effective by saving labor and materials, repurposing underused urban spaces, and creating commercial and cultural value through heritage-led projects [15]. These advantages have made adaptive reuse a key element of sustainable urban planning worldwide.

Material conservation in adaptive reuse projects is sometimes viewed as an afterthought, usually from a heritage preservation perspective, although these efforts often yield broader sustainability benefits. There is less emphasis on the direct connection between material conservation and larger sustainability goals, although work by Plevoets & Van Cleempoel and Australia ICOMOS (2013) focuses on preserving the historical character of buildings [7]. As Gorgolewski notes, conserving materials like wood, stone, and brick significantly reduces the environmental impact of building interventions [4]. Carbon reduction can also be achieved by adopting measures that lower the energy required to produce new materials through conservation efforts [5].

While not less significant, the economic aspect of material conservation in adaptive reuse is often overlooked. As Bullen and Love mention, projects involving adaptive reuse and material conservation are often linked to lower building costs, shorter timelines, and better project efficiency [16]. Additionally, using high-quality historic materials can boost the marketability and value of the property, especially in developments that blend modern functionality with heritage aesthetics. This results in material conservation in adaptive reuse projects being both economically and environmentally wise.

Still lacking, however, are systematic frameworks in the literature that evaluate the direct effects of material conservation on the environmental and economic performance of adaptive reuse. According to Velthuis & Spennemann, no standard methodologies exist to measure these impacts [6], and recent studies call for an integrated approach where material conservation is a proactive element within sustainability models [17].

Since 2017, additional research has increasingly focused on the link between adaptive reuse and material conservation. Reusing building materials is particularly important for avoiding the environmental impacts of producing new materials. Guidetti and Ferrara explored how reusing materials reduces environmental impacts and supports sustainability goals throughout a building's life cycle [12]. Recycling materials is beneficial not only for the environment but also for the economy. Because manufacturing new materials consumes a lot of energy, recycling in adaptive reuse projects can significantly save energy and reduce carbon emissions [4] [5].

According to research conducted through 2021, adaptive reuse performs better when material conservation strategies are integrated early in the design process. This approach reduces environmental impacts and enhances the sustainability of projects. Studies show that including these strategies early on not only decreases environmental impacts like carbon emissions and material waste but also supports the socio-cultural sustainability of the built environment. Designing with adaptive reuse potential in mind helps prevent many of the implementation challenges that arise later in the project lifecycle and promotes the development of low- or zero-carbon buildings in urban settings [13].

The cost savings and environmental benefits of adaptive reuse have been more clearly confirmed by studies conducted in 2023, which also showed how material conservation contributes to sustainable design. Material conservation is a key strategy for enhancing long-term sustainability, write Guidetti and Ferrara, and adaptive reuse projects significantly reduce carbon emissions [12]. According to this study, since reused materials tend to be cheaper, adaptive reuse is both economically and environmentally advantageous. Additionally, the elimination of processes related to manufacturing and transporting new materials shortens the project's timeline.

The literature review highlights research connecting measurable sustainability outcomes with material conservation practices. Researchers and practitioners can more effectively implement adaptive reuse solutions if they recognize the reuse of materials as an essential aspect of sustainable design, rather than merely a cultural or heritage-based practice. In addition to providing a better understanding of how material preservation influences adaptive reuse toward long-term sustainability, this approach could lead to more detailed analyses of sustainability. Current research has further explored adaptive reuse and material preservation in relation to supporting ecological and economic sustainability. By 2023, there have been calls to establish systematic methods to implement these measures more efficiently. It has been established that material preservation must be considered part of environmental sustainability goals and within the framework of cultural heritage protection. This study aims to fill such gaps and examine more efficient ways to apply material preservation techniques in adaptive reuse projects.

4. CASE STUDIES

This article explores how material conservation strategies in adaptive reuse influence sustainability through four detailed case studies: Salt Galata (Istanbul, Turkey), CerModern (Ankara, Turkey), Tate Modern (London, United Kingdom), and Gasometer City (Vienna, Austria). The cases were chosen to examine the link between material conservation and sustainability outcomes and to enable a comparative analysis of how such strategies are applied across different cultural, regulatory, and urban settings. Selection criteria included alignment with research goals, focus on sustainability, project size and type, and diversity of historical and urban backgrounds. Each project offers concrete examples of material conservation and sustainable adaptive reuse, including measures such as energy efficiency, material reuse, and reduction of environmental impacts. The case studies cover a wide range of building types, functions, and reuse approaches, from small-scale interventions in industrial heritage sites (Salt Galata) to large-scale projects in cultural and urban institutions (Tate Modern and Gasometer City), representing both local (Turkey) and international (United Kingdom and Austria) contexts.

This method enables a comparative evaluation of material conservation practices across different scales, types, and settings, help deepen the understanding of their effects on sustainability. The article discusses both technical and architectural aspects of material conservation, aiming to offer practical guidelines for common strategies, contextual adjustments, and future adaptive reuse projects. It examines how these strategies impact the social, economic, and environmental aspects of sustainability.

Table 2. *Overview of Case Study Parameters*

Case Study	Location	Original Function	Reused Function	Key Materials Retained	Data Sources
Salt Galata	Istanbul, TR	Bank	Cultural & Research Center	Stone façade, marble flooring	Academic journals, SALT archive
Cer-Modern	Ankara, TR	Railway Workshop	Contemporary Art Center	Steel trusses, brick walls	Museum records, architectural analysis
Tate Modern	London, UK	Power Station	Museum of Modern Art	Brick shell, steel structure	Museum archives, academic literature
Gasometer	City Vienna, AT	Gas Storage Tanks	Mixed-Use (residential, commercial)	Brick exteriors, steel frames	Urban renewal reports, architectural studies

4.1. Case Study 1: Salt Galata – Istanbul, Turkey

4.1.1. Historical and Architectural Background

Salt Galata, which is situated in the Galata neighborhood of Istanbul, was first built in 1892 as the headquarters of the Imperial Ottoman Bank. It was designed by French Ottoman architect Alexandre Vallaury, who is renowned for fusing orientalist ornamental elements with neoclassical design principles, which are typical of Ottoman institutional architecture from the late 19th century [18]. Figure 1 shows A. Vallaury's façade drawing of Bankalar Caddesi. The structure was used for administrative, archival, and financial purposes and was crucial to the Ottoman Empire's financial system's modernization. Figure 2 shows views of the Former Ottoman Bank / SALT Galata.

Initiated by Garanti Bankası Platform Garanti Contemporary Art Center and designed by Mimarlar Tasarım, the adaptive reuse project was finished in 2011 under the auspices of SALT, a cultural organization created to foster artistic creation and research. The historic bank building was converted into a multipurpose cultural center with exhibition areas, a research library, an auditorium, and archive facilities as part of the project [19].

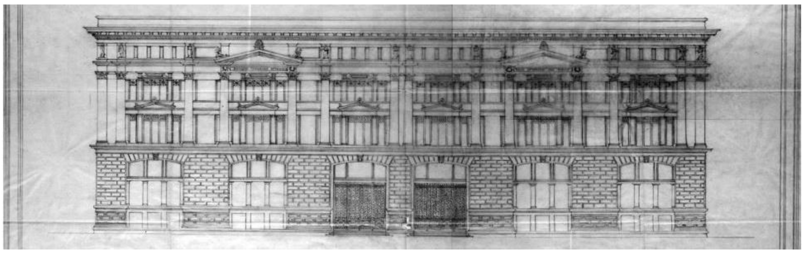


Figure 1. *A. Vallaury's façade drawing of Bankalar Caddesi* [20]

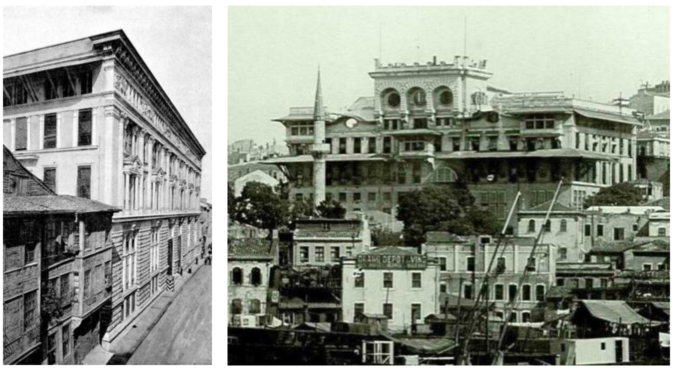


Figure 2. *Views of the Former Ottoman Bank / SALT Galata* [21]

4.1.2. Material Conservation Strategies

The preservation and restoration of original materials and architectural features were given top priority in the Salt Galata project, which used a heritage-sensitive conservation approach. Among the primary materials preserved were:

- Stone masonry walls and facades (local limestone and marble),
- Cast iron structural elements (beams, columns, and balustrades),
- Wooden floors, doors, and staircases,
- Ornamental plasterwork and decorative finishes.

In accordance with international conservation charters like the Venice Charter (1964), the exterior and interior surfaces were cleaned with minimal physical intervention, stabilized mechanically, and repaired using traditional materials that were compatible [22]. Details of the bank's facade are as shown in the Figure 3.

Key strategies included:

- Minimum Intervention: Only what was required for both structural integrity and functional adaptation was addressed.
- Reversibility: Contemporary additions were made to be both reversible and unique from the original structure.
- Material Compatibility: New materials used for additions or repairs were selected based on their ability to work chemically and physically with the original fabric [23].

Additionally, wherever feasible, historic materials were conserved and reused in their original locations. Archival vault doors, for instance, were kept and incorporated into the new spatial arrangement, and the original flooring materials were preserved and strengthened. Figure 4 shows the entrance and gallery hall of the bank before restoration.

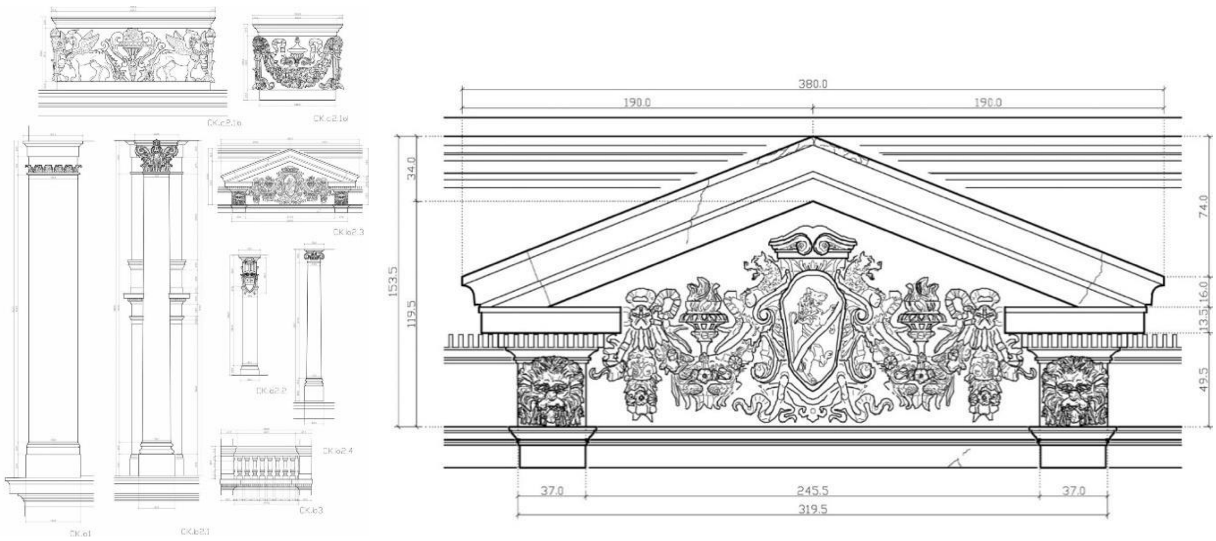


Figure 3. *Facade Details of the Bank* [21]

Figure 4. *Entrance and Gallery Hall of the Bank* [24]

4.1.3. Integration of Modern Systems

Modern mechanical, electrical, and circulation systems had to be integrated for the reuse project, including:

- HVAC systems,
- Elevators and staircases (Figure 5),
- Lighting infrastructure (Figure 6),
- Fire safety systems.

All new components were structurally and aesthetically isolated from the historic shell during these non-intrusive interventions. To reduce the impact on the original masonry and timber structures, for example, the HVAC systems were installed through false floors and ceilings [25]. To distinguish the modern layer from the historical one, new elements were made of steel and glass.

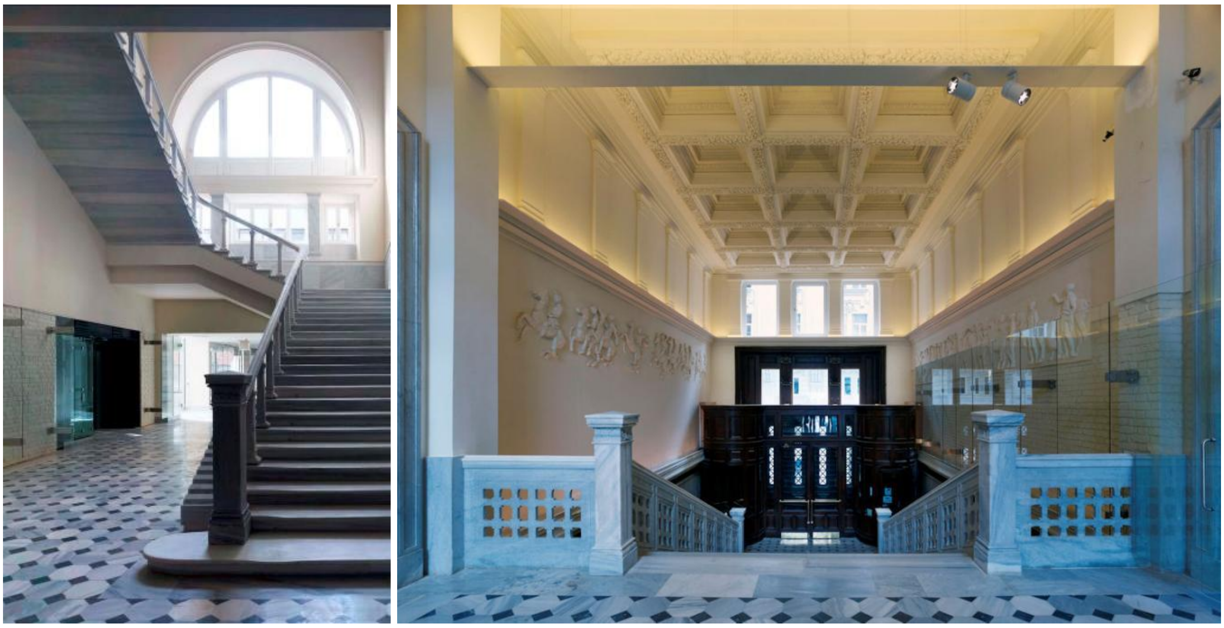


Figure 5. *Entrance Hall Restoration of the Bank* [26]

Figure 6. *Gallery Hall Restoration of the Bank. Re-introducing daylight into the building's interior* [26]

4.1.4. Sustainability Outcomes Related to Material Conservation

The economic and environmental facets of sustainability were directly impacted by material conservation:

a) Environmental Sustainability

- Reducing embodied carbon emissions: The thick stone walls, wooden flooring elements and iron structural elements of the building were preserved and re-functioned. In this way, the need for new material production was reduced, thus reducing embedded energy consumption and carbon emissions.
- In-situ preservation and repair of building materials: Original architectural components (stone walls, joinery, iron parts) were repaired instead of demolished and integrated into the new spatial order. Thus, construction waste from demolition was significantly reduced.
- Preservation and improvement of passive performance: Thanks to the thermal mass provided by thick stone walls, the interior temperature was made more stable and the need for mechanical air conditioning was reduced. The preservation of wide window openings contributed to natural lighting and ventilation [27].

b) Economic and Functional Sustainability

- Cost savings in materials: Preserving and reusing existing original materials (stone walls, poured concrete floors, metal joinery) reduced the need for new building materials and lowered the project cost.
- Extending the life of the structure: The load-bearing system, façade and interior details of the structure were restored and brought into line with contemporary standards. Thus, both physical durability and service life were increased.
- Cultural tourism and public use: Salt Galata was re-functioned as a cultural institution. With this transformation, the structure gained an active public use while preserving its place in urban memory. The project contributed to the survival of cultural heritage not only physically but also socially and economically. The re-functioning of Salt Galata enabled it to become a cultural center in the heart of Istanbul. This process made a significant contribution to urban renewal and cultural economy, and this model inspired other cities [27].

Salt Galata is a well-known illustration of how adaptive reuse initiatives that conserve materials can directly contribute to the objectives of environmental and financial sustainability. The project shows that maintaining original materials while incorporating contemporary systems can coexist in a way that upholds historical integrity and enhances the built heritage's longevity, usability, and ecological performance. Figure 7 shows the interior of SALT Galata after adaptive reuse, transformed into a cultural center in the heart of Istanbul.

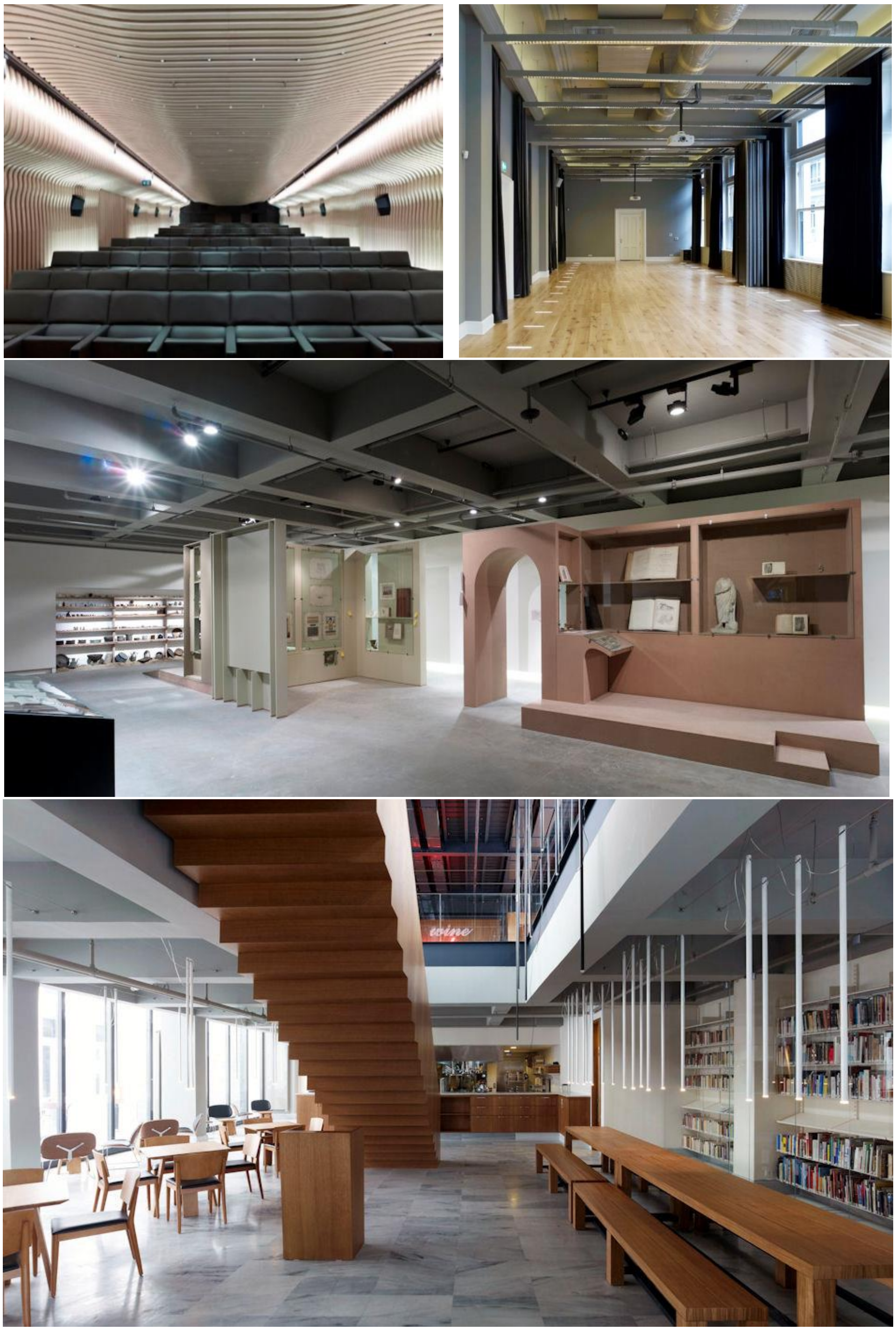


Figure 7. *Adaptive reuse of SALT Galata: A cultural center in the heart of Istanbul* [26]

4.2. Case Study 2: CerModern – Ankara, Turkey

4.2.1. Historical and Architectural Background

Located in the Sıhhiye district of Ankara, CerModern occupies a portion of the former Ankara Railway Workshop Complex, which was first built in 1927 as part of the early industrial modernization initiatives of the Turkish Republic. The Turkish State Railways (TCDD) constructed the complex, which showcased early Republican rationalist architectural tendencies influenced by the Bauhaus movement and German industrial architecture [18]. Figure 8 shows the pre-restoration state of the Hangar.

Beginning in the early 2000s and ending in 2010, the adaptive reuse project turned the defunct maintenance workshop into CerModern, a center for contemporary art. Semra and Özcan Uygur (Uygur Architects) designed the architectural intervention, which prioritized cultural revitalization, preservation, and openness [28].

Figure 8. *The pre-restoration state of Hangar* [29]

4.2.2. Material Conservation Strategies

The preservation and restoration of the original surface and structural materials were given top priority during the adaptive reuse process, and this included:

- Reinforced concrete load-bearing structure,
- Steel roof trusses and support systems,
- Brick infill walls and surfaces,
- Timber window frames and doors,
- Concrete flooring and industrial fittings.

Internationally recognized principles, such as the Venice Charter (1964) and the Burra Charter (1999), were adhered to by conservation strategies, especially with respect to minimal intervention, reversibility, and legibility of interventions [30]. Figure 9 shows the post-restoration view of the hangar structure.
Key practices included:

- Cleaning and stabilizing concrete and steel structural elements without encasing or concealing them,
- Structural components that are selectively reinforced with appropriate materials and methods (e.g., epoxy injection in concrete),
- Preservation of the original fittings, wear marks, and patina wherever possible in order to maintain the industrial character,
- Integration of modern steel and glass components for circulation and display spaces that stand out from the historic structure.

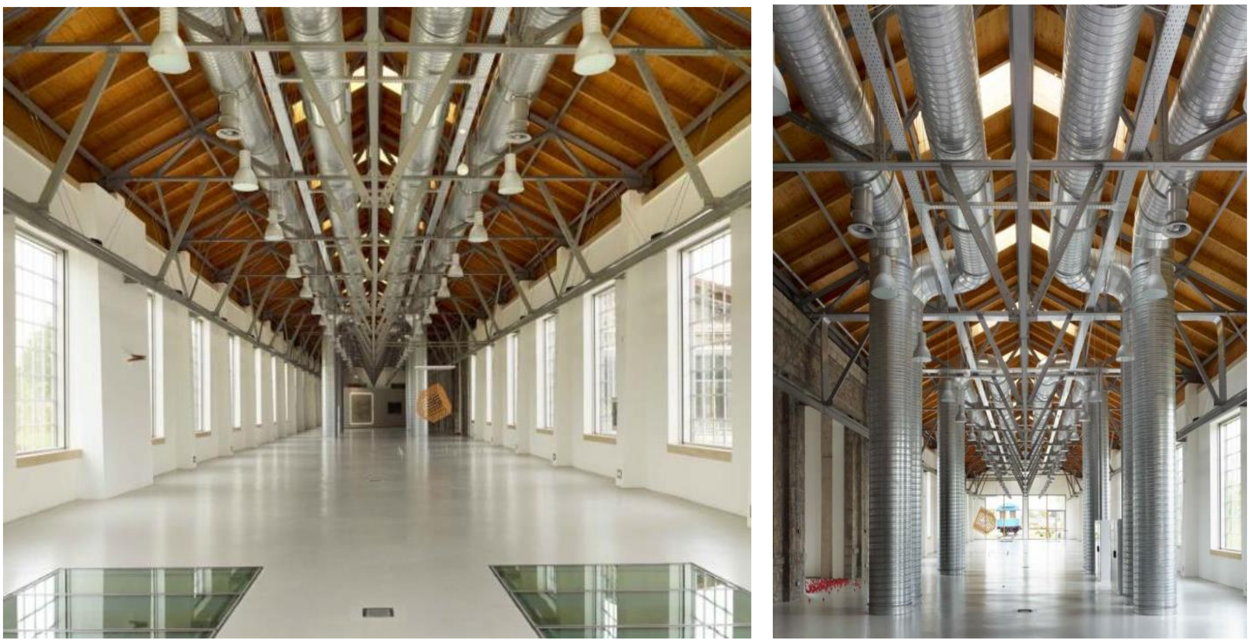


Figure 9. *Post-restoration view of the hangar structure* [29]

4.2.3. Integration of Modern Systems

The building's new cultural purpose required the introduction of modern infrastructure, which includes:

- HVAC systems,
- Lighting and audio-visual equipment,
- Fire safety and emergency systems,
- Accessibility ramps and elevators,
- Exhibition installation infrastructure.

Figure 10 shows the exhibition area and structural details. By integrating these systems in a non-intrusive manner, they were frequently positioned inside newly constructed interior partitions that were intended to be aesthetically secondary to the preserved structure or along existing service routes. Without compromising the original workshop layout's spatial coherence, steel-framed additions and glass curtain walls were utilized to provide circulation and climate control [28].

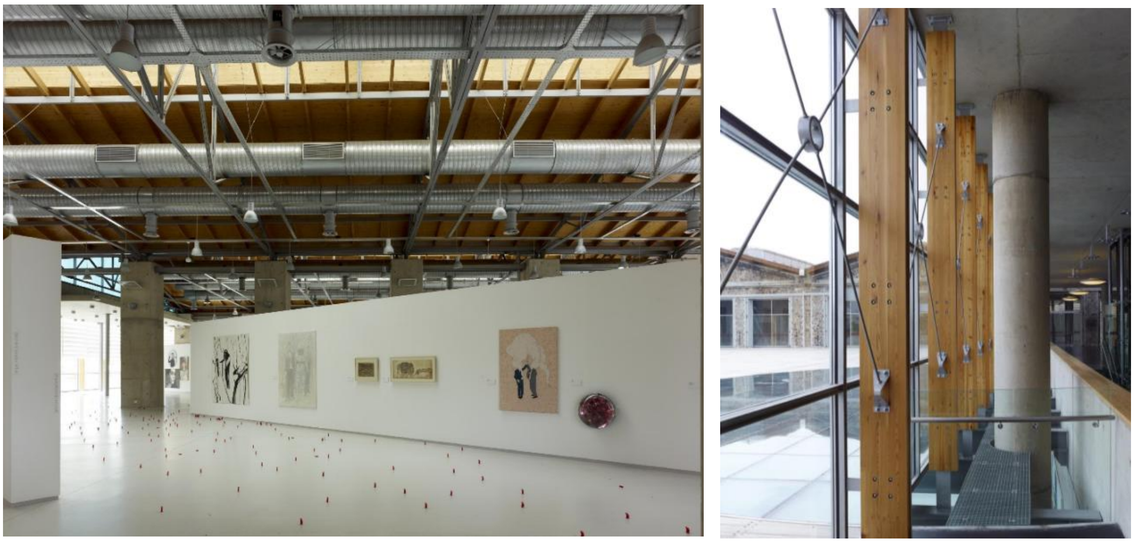


Figure 10. *Exhibition area and structural details* [29]

4.2.4. Sustainability Outcomes Related to Material Conservation

a) Environmental Sustainability

● Reuse of building materials and reduction of embodied carbon: Reinforced concrete carrier system, steel roof trusses and brick-filled walls were preserved and integrated into the structure. Thus, environmental impacts were reduced by reducing the production and transportation of new materials.

● Preservation of passive environmental features: Passive features of the original structure such as high ceilings, openable windows and reinforced concrete thermal mass were preserved and improved. Thus, natural ventilation and energy efficiency were provided.

● Reduction of construction waste by preventing demolition: Thanks to the preservation and reinforcement of historical materials in situ, construction waste that will occur during the transformation process of the structure was kept to a minimum.

b) Economic and Functional Sustainability

● Contribution to Urban Renewal: CerModern has re-functioned the abandoned industrial zone of Ankara, thus increasing the real estate values around it and making a significant contribution to urban renewal. This process has improved the social and economic structure of the region. Figure 11 shows the site plan of CerModern and the Presidential Symphony Orchestra Concert Hall, a cultural landmark in Ankara.

● Self-Sufficient Economic Ecosystem Based on Art, Design and Creative Industries: The preserved architectural identity and unique spatial character have made the region attractive to cultural institutions, artists and tourists, while enabling the development of artistic and cultural activities. In this way, CerModern has become a center where artistic production and cultural heritage meet.

● Reduction in Maintenance Costs: In the CerModern project, maintenance costs have been reduced by preserving and improving old industrial building elements. This process has been achieved by reusing existing materials and the environmental impacts of the construction have been reduced.

● Economic Contributions and Investment Attractiveness: The cultural and artistic environment created by CerModern has become attractive to regional investors. Additionally, the project has provided significant gains in terms of environmental and financial sustainability [31].

The CerModern project serves as an example of how adaptive reuse frameworks combined with material conservation can effectively support economic and environmental sustainability objectives. Without sacrificing the site's ecological performance or historical authenticity, an industrial relic was transformed into a thriving public institution through the careful integration of new systems and functions while maintaining the site's structural and material heritage. Figure 12 shows CerModern Arts Center.

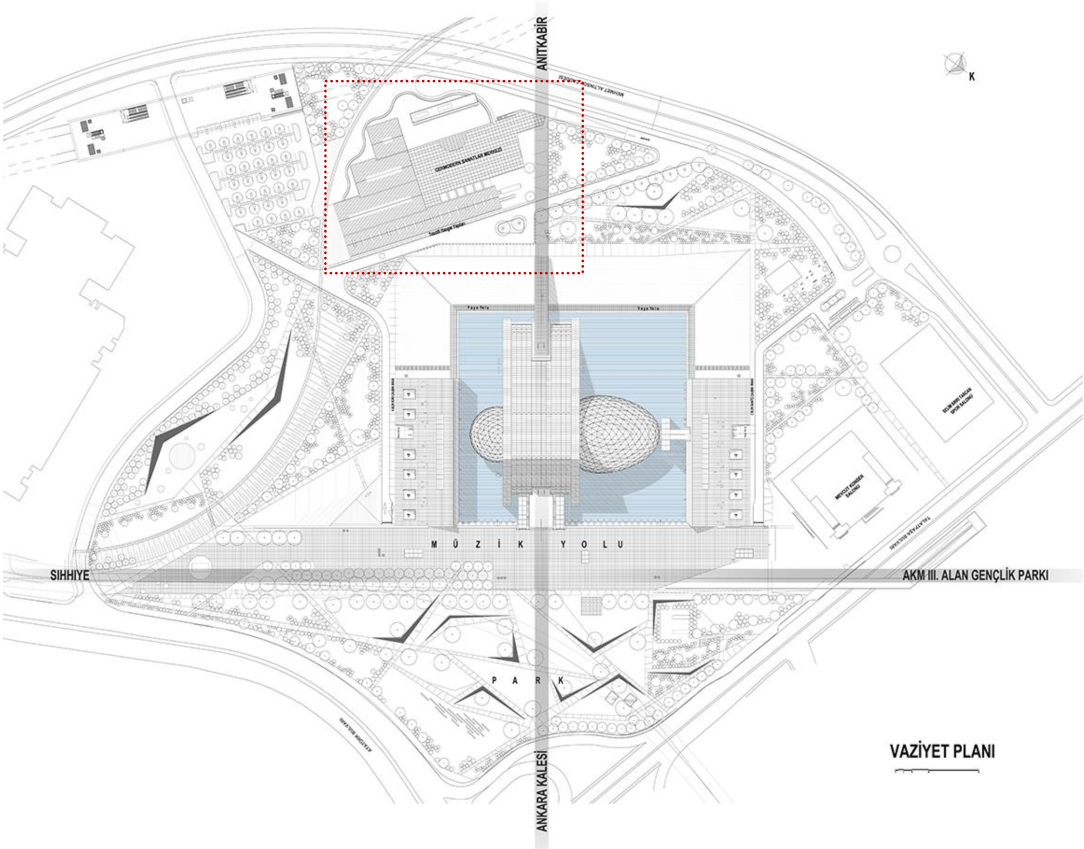


Figure 11. *Site Plan of CerModern and Presidential Symphony Orchestra Concert Hall, A cultural landmark in Ankara* [28]

Figure 12. *CerModern Arts Center* [29]

4.3. Case Study 3: Tate Modern – London, United Kingdom

4.3.1. Historical and Architectural Background

The original structure, designed by Sir Giles Gilbert Scott and constructed in two phases between 1947 and 1963, is notable for its steel frame, central chimney, and monumental brick facade (Figure 13). The structure was left unoccupied for almost two decades after it was decommissioned in 1981.

In 1995, Herzog & de Meuron was chosen by the Tate Gallery to oversee the adaptive reuse of the building into a museum of contemporary art. After the makeover was finished in 2000, a significant addition known as the Blavatnik Building was added in 2016 (Figure 14).

Figure 13. *Steel frame, central chimney and brick facade construction* [32]

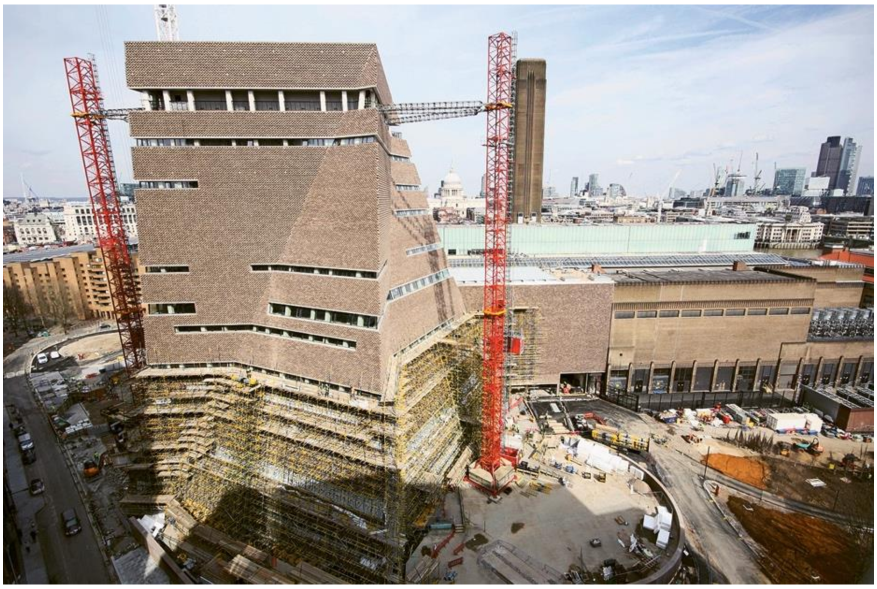


Figure 14. *Blavatnik Building was added in 2016* [32]

4.3.2. Material Conservation Strategies

By preserving the original power station's internal volumes, steel framework, and external brick envelope, the Tate Modern project implemented a conservation-through-reuse strategy.

Key conservation strategies included:

● Maintaining the building's visual identity and the surrounding urban fabric by keeping and cleaning the original brick façade.

● Preservation of the turbine hall, a central public area that was once an industrial void measuring 155 meters in length and 35 meters in height, can be seen in the building section. (Figure 15).

● Restoration of the existing roof and steel framing, including adaptation for new uses and reinforcement for structural integrity.

● Combining new materials that are still easily identifiable with the selective reuse of preexisting materials, such as steel components and staircases.

By avoiding excessive concealment or aesthetic homogenization and preserving the building's raw material character, the design team implemented the principle of minimal intervention (Figures 16).

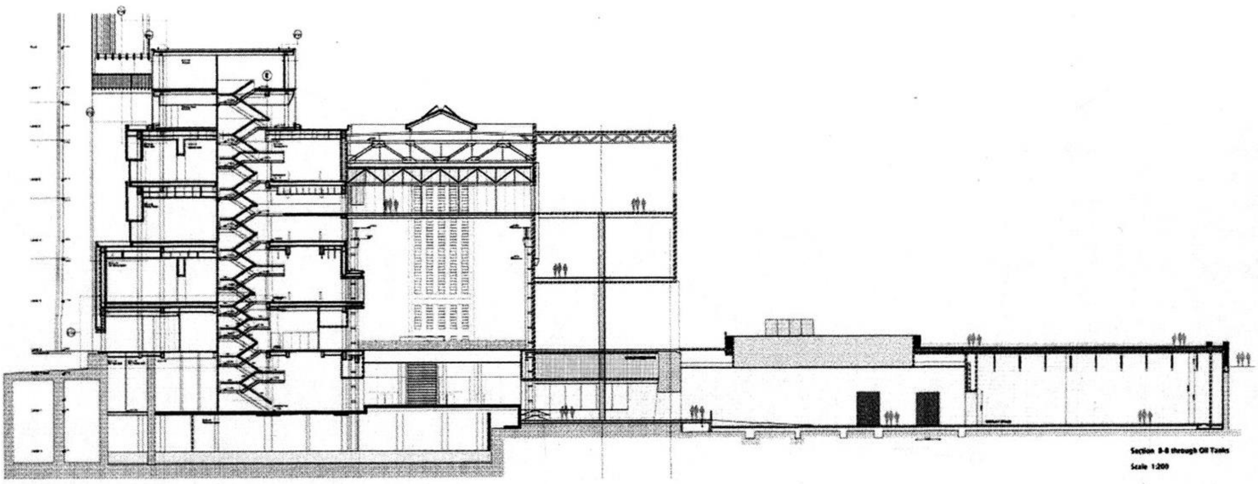
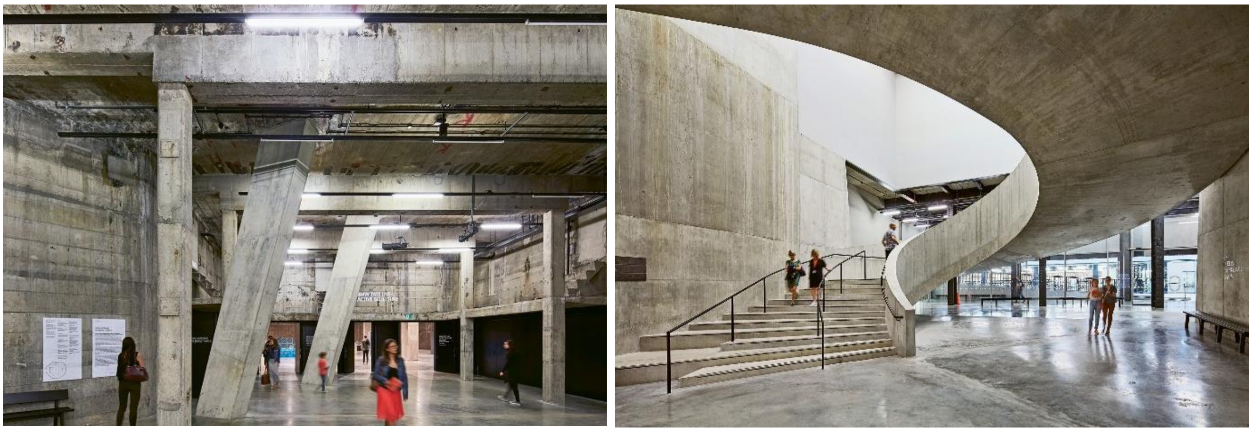


Figure 15. *Section through Boiler House, Turbine Hall, Switch House, and Oil Tanks at Tate Modern* [33]



Figures 16. *Tate Modern Museum* [32]

4.3.3. Integration of Modern Systems

To support its new cultural role, Tate Modern implemented the following:

- Modern climate control systems for preserving artwork,
- Lighting and acoustic systems suitable for flexible exhibition layouts,
- Public access points such as recently added elevators, escalators, and stairs,
- Safety and accessibility systems that meet current codes.

The industrial grandeur of the building was preserved through the integration of these features, which were often installed within the existing structural grid to avoid disruptive spatial changes [34]. Similar concepts were applied in the expansion of the Blavatnik Building, which used textured brickwork to retain architectural character while visually connecting to the original power station. Figure 17 shows brickwork details of the Blavatnik Building.

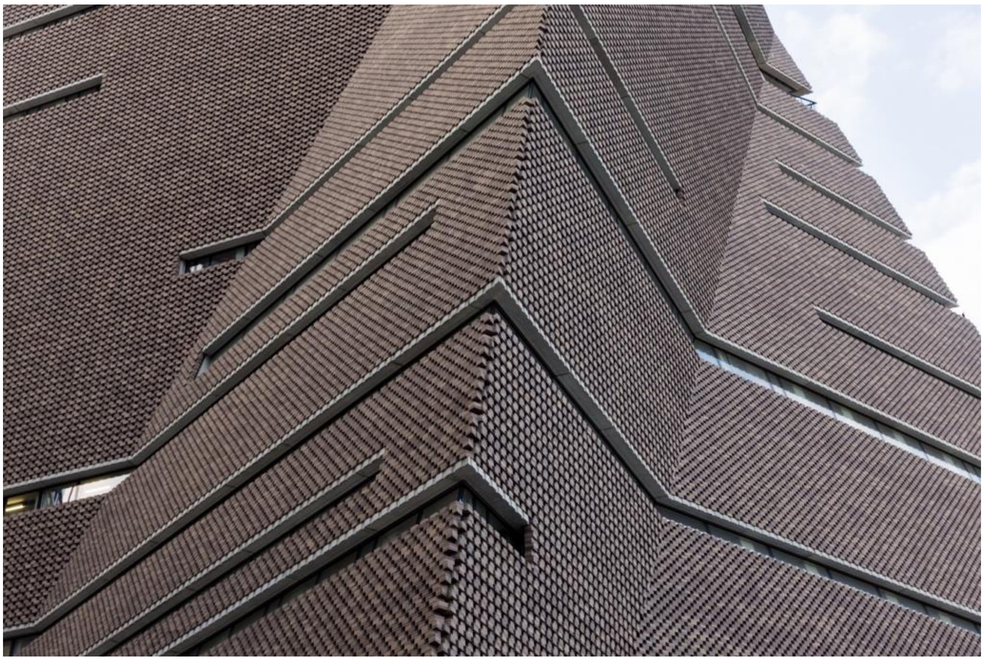


Figure 17. *Brickwork details of Blavatnik Building* [33]

4.3.4. Sustainability Outcomes Related to Material Conservation

a) Environmental Sustainability

- By conserving thousands of tons of steel and brick, material reuse greatly decreased the environmental costs related to demolition and new construction.
- Lower life-cycle carbon emissions resulted from the retention of the structural shell and turbine hall, which decreased embodied energy.
- Passive environmental strategies are used in the building, such as daylighting through existing openings and clerestory windows and natural ventilation in large spaces.
- High environmental standards, including BREEAM Excellent certification, were met in the design of the 2016 expansion.

b) Economic and Functional Sustainability

- Reusing the iconic Bankside Power Station helped revitalize the South Bank by enabling the quick cultural reactivation of a post-industrial area.
- By maintaining sturdy, high-quality materials, material conservation allowed for significant cost savings in both construction and ongoing maintenance.
- The preserved architectural character had a big impact on the museum's branding, increasing public engagement, bringing in millions of visitors annually, and ensuring long-term financial sustainability.

One well-known example of extensive adaptive reuse is Tate Modern, where material preservation is essential to attaining sustainability on all levels—environmental, cultural, and financial. The project effectively incorporated contemporary cultural functions while maintaining the building's sturdy industrial materials and spatial identity, all without sacrificing ecological performance or architectural authenticity (Figure 18).

Figure 18. *Adaptive Reuse of Tate Modern: preservation of industrial materials and spatial identity* [33]

4.4. Case Study 4: Gasometer City – Vienna, Austria

4.4.1. Historical and Architectural Background

Four sizable cylindrical gas tanks that were built as part of the Simmering gasworks between 1896 and 1899 make up Vienna's Gasometers. These buildings, which were designed by Franz Klüpfel and were initially used to store coal gas, are important examples of industrial brick architecture from the late 19th century [35]. Each gasometer has steel-framed internal structures and load-bearing brick façades. They are about 70 meters in diameter and 60 meters high. (Figure 19).

The gasometers had not been used since they were decommissioned in 1984 until the City of Vienna started an adaptive reuse project in the late 1990s. Each gasometer was redesigned by a different architect: Wilhelm Holzbauer (Gasometer D), Manfred Wehdorn (Gasometer C), Coop Himmelb(l)au (Gasometer B), and Jean Nouvel (Gasometer A) after the conversion into a mixed-use residential and commercial complex was finished in 2001.

Figure 19. *Four gasometers were built in a period of three years, between 1896 and 1899* [36]

4.4.2. Material Conservation Strategies

The adaptive reuse project allowed for flexibility in internal reconfiguration while preserving the historically protected external brick façades.
Key conservation approaches included:

- The original brick masonry was thoroughly cleaned and restored, kept, and structurally stabilized with anchors and internal reinforcement rings [37].
- Reinforcement and, when practical, partial reuse of the original steel structures, including a few chosen beams and columns.
- New interior structures that are built using modern materials and technologies and are easily identifiable from the historic fabric are inserted within the brick shells.
- Adherence to the Austrian Monument Protection Act, which mandates that renovation and intervention procedures have as little negative impact as possible on protected architectural elements.

The reuse project employed the "building within a building" concept, which enables both modern functionality and heritage protection by preserving the external shell while allowing for internal flexibility (Figure 20).

Figure 20. *Apartment Building Gasometer B, Vienna.* [38]

4.4.3. Integration of Modern Systems

The gasometers were converted into a multipurpose urban complex by the redevelopment project, which consists of:

- Approximately 800 residential units,
- A shopping mall,
- A cinema,
- Offices and event spaces,
- Student housing and cultural venues.

To maintain their integrity and ensure compliance with current building codes and energy standards, modern infrastructure—such as HVAC systems, elevators, emergency access, and acoustic insulation—was installed inside the new buildings separately from the historic walls. Figure 21 illustrate the zones and layouts within this multipurpose urban complex.

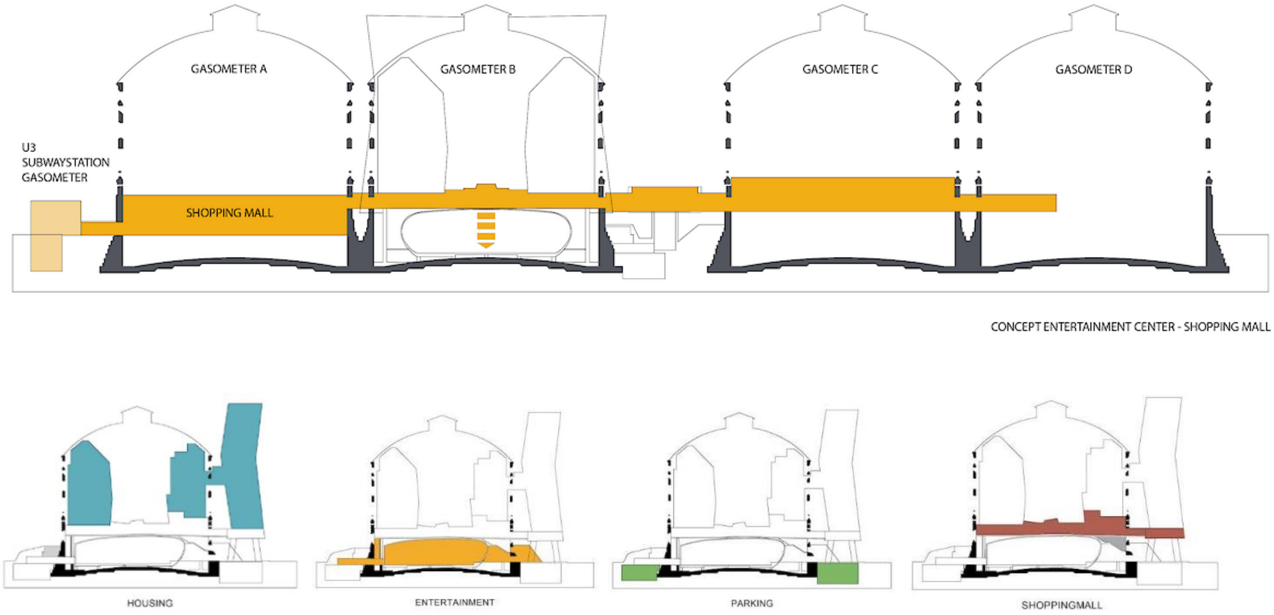


Figure 21. *Multipurpose urban complex zones* [38]

4.4.4. Sustainability Outcomes Related to Material Conservation

a) Environmental Sustainability

- By preserving the brick envelope, the need for new building supplies was greatly decreased, which helped to mitigate construction waste and save embodied energy.
- The environmental costs of demolition and new land use development were avoided by extending the life cycle of industrial heritage materials through adaptive reuse.
- The energy efficiency of the interior spaces was improved by passive techniques like insulation from the thick brick walls and natural thermal mass.
- The project promoted low-carbon urban mobility by integrating with Vienna's public transportation system.

b) Economic and Social Sustainability

- The Gasometer redevelopment revitalized a previously underutilized site and helped to revitalize the Simmering district's urban area.
- The addition of student residence halls and subsidized housing in a historically significant location helped to support housing affordability.
- The area has become a symbol of Vienna's adaptive reuse policies as a result of the preservation of the gasometers' industrial identity, which has improved cultural continuity [39].

The Gasometer City project serves as an example of how adaptive reuse combined with material conservation can successfully promote social, economic, and environmental sustainability in extensive urban redevelopment. The project exemplifies a balanced approach to heritage preservation and modern urban living by conserving industrial architectural heritage through meticulous conservation and creative internal adaptation. Figure 22 shows the Gasometer Complex in Vienna, where the historic gas holders were adaptively reused as a mixed-use urban center.

Figure 22. *Gasometer Complex in Vienna: Adaptive reuse of historic gas holders into a mixed-use urban center*. [40]

5. COMPARATIVE EVALUATION OF CASE STUDIES

Key insights and practical implications on how material conservation in adaptive reuse contributes to environmental, economic, and cultural sustainability are revealed through the comparative analysis of Salt Galata (Istanbul), CerModern (Ankara), Tate Modern (London), and Gasometer City (Vienna). These strategies highlight how material conservation aligns with sustainability objectives and provides guidance for integrating heritage preservation into contemporary adaptive reuse projects.

5.1. Shared Strategies in Material Conservation

A common approach among the four projects is to retain the original façade and structural materials like steel, timber, stone, and brick. The approach reduces embodied carbon associated with the production of new materials and prevents demolition, thereby lowering environmental costs without sacrificing historic authenticity [2][14]. Flexibility in reuse, as seen in examples such as Gasometer City and Tate Modern, has been achieved through reversible and non-invasive interventions, ensuring that original materials remain intact or can be recovered in the future. The use of dry construction systems and modular infills further supported adaptability. When considered together, these approaches suggest that material conservation can inform repeatable strategies balancing heritage preservation with environmental performance.

5.2. Contextual Adaptation and Cultural Integration

The case studies illustrate how material conservation strategies are adapted in response to different cultural and urban contexts. Salt Galata and CerModern focus on local materials and traditional references, which enhances cultural continuity and promotes a sense of place within the urban contexts. In contrast, Tate Modern and Gasometer City employ a more international architectural language, integrating material conservation into large-scale urban renewal projects where heritage value is combined with contemporary development needs [41]. This contrast indicates that the effectiveness of material conservation is not limited to the technical preservation of materials; it is also influenced by the cultural and regulatory contexts in which these projects exist. The results indicate that approaches tailored to their context are crucial for ensuring that material conservation methods not only aid in heritage preservation but also support wider sustainability goals, such as social cohesion and cultural resilience.

5.3. Environmental Sustainability Outcomes

Reduction in carbon emissions, energy efficiency, and waste reduction are some of the ways in which conserving materials benefits the environment. For example, the need for large amounts of new material was avoided in Gasometer City and Tate Modern by preserving the brick envelopes, and operational efficiency was also enhanced through adaptive energy systems like district heating and passive ventilation. Salt Galata's LEED certification illustrates that historic projects can meet modern sustainability standards without losing their significance [42]. These findings reinforce the environmental benefits of material conservation, providing empirical support for its integration as a key sustainability strategy in adaptive reuse.

5.4. Economic Revitalization and Feasibility

Material conservation-based adaptive reuse has proven to be both economically and socially advantageous. All four projects generated new revenue streams by turning vacant buildings into commercial, cultural, or mixed-use spaces. While Gasometer City and Tate Modern enhanced urban destinations as major attractions, Salt Galata and CerModern boosted the cultural economy by demonstrating that old buildings can be appreciated through modern economic principles [2][43]. These examples show that preserving materials safeguards architectural integrity while simultaneously generating economic benefits, making conservation a viable strategy for sustainable project planning.

5.5. Challenges and Critiques

Such projects reveal flaws despite their success. In Tate Modern and Gasometer City, for example, where adaptive reuse could have disrupted local communities or favored market-driven agendas, issues of gentrification and commercialization arose [44]. Conversely, Salt Galata and CerModern had to make careful design decisions balancing heritage integrity and modern use due to the conflict between functional modernization and authentic preservation. These challenges highlight contextual limitations and the need for tailored strategies, offering insights into potential risks and issues for sustainable adaptive reuse in different urban settings.

This comparative analysis underscores the key benefits of material conservation in adaptive reuse, including measurable environmental and economic gains alongside the safeguarding of architectural heritage. These findings support the main argument of the article, which is that material conservation is one of the most crucial sustainability strategies in architectural transformation.

Table 3. *Comparative Evaluation of Case Studies in Terms of Material Conservation and Sustainability*

Criterias	**Salt Galata**	**CerModern**	**Tate Modern**	**Gasometer City**
1. Material Conservation Approach	The original façade, stone walls and structural elements were preserved and new systems were integrated [27].	The reinforced concrete structure was reused while preserving the industrial identity [31].	The brick façade was preserved, and the interior was rearranged with modular systems [34].	The steel and brick structure was preserved, and recyclable modules were added [37].
2. Integration with Cultural and Urban Context	The Ottoman Bank's past has been integrated with culture, and its place identity has been strengthened [27].	Industrial heritage has contributed to Ankara's cultural life by transforming into an art-focused space [28].	It has been integrated into London's image with an international identity reflecting modern art [41].	Industrial memory has been preserved and integrated into urban growth with residential, cinema and commercial functions [39].

3. Environmental Sustainability Contribution	LEED certified; energy efficiency has been achieved with natural lighting and passive systems [42].	The need for new materials has been reduced, durable structural components have been re-evaluated [31].	Carbon emissions have been reduced by preserving the brick facade, and passive ventilation has been used [34].	The existing shell has been preserved, and energy efficiency has been increased with district heating systems [34].
4. Economic and Functional Sustainability	By re-functioning as a cultural center, economic revitalization was achieved in the city center [27].	A sustainable economic ecosystem was created for art and creative industries [31].	Significant sources of income were created through tourism and art [43].	Long-term economic sustainability was achieved with commercial, social and residential functions [2].
5. Challenges and Criticisms	The need for modern use was balanced while remaining loyal to the historical texture [27].	A balanced intervention was required between functional modernization and identity preservation [28].	Exclusion of local people due to gentrification and commercialization was criticized [44].	The social effects of market-oriented transformation were discussed [39].

6. CONCLUSION

This article examined the role of material conservation in adaptive reuse through four in-depth case studies—Salt Galata (Istanbul), CerModern (Ankara), Tate Modern (London), and Gasometer City (Vienna)—to determine how preserving existing building material is an element in attaining sustainability outcomes. The findings add several significant contributions to the research questions.

The results show that material retention has been identified as making direct contributions to sustainability impacts in adaptive reuse through reducing the demand for new materials, lowering embodied energy, and reducing construction waste and greenhouse gas emissions. Beyond environmental performance, preservation of original materials preserves architectural integrity and cultural continuity, and thereby links adaptive reuse to broader sustainability agendas.

The case studies show that recycling materials bring various benefits in environmental, economic, and cultural aspects. Economically, adaptive reuse for conservation creates new value streams by repurposing outdated buildings as productive ones, as demonstrated by the Turkish and European examples. Culturally, incorporating local materiality and the layering of history helps preserve spatial identity and increases resilience in urban areas. Environmentally, retaining materials improves efficiency and supports low-carbon building practices.

Comparative analysis emphasizes context-specific responses to challenges. Turkish examples illustrate the delicate balance between modernization and preservation where weak regulatory institutions and limited resources are common. In contrast, European examples feature institutional arrangements and policies that facilitate widespread reuse and the systematic integration of sustainability practices. Such differences support the idea that material conservation measures must be understood within their regulatory and sociocultural contexts. Overall, the analysis shows that material conservation is not just a secondary result of adaptive reuse but a key method for promoting sustainable architectural transformation. By connecting technical preservation with economic, social, and environmental goals, material conservation serves as a practical set of principles for maintaining heritage and supporting long-term adaptability.

This article contributes to adaptive reuse literature by thoroughly exploring the understudied link between material conservation and sustainability. Although based on a small set of case studies, the findings suggest that conservation-focused approaches provide useful insights for future projects, especially regarding integrating cultural heritage within modern sustainability initiatives. Future research can build on this by testing these insights in different regions or measuring long-term sustainability benefits more systematically.

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