DOI: 10.23817/2024.defarch.3-10

OLENA OLIYNYK
ORCID: 0000-0002-6786-0633
National Academy of Fine Arts and Architecture, Ukraine

THE LATEST TRENDS IN THE CULTURAL HERITAGE PRESERVATION ON THE PRINCIPLES OF SUSTAINABLE DEVELOPMENT

NAJNOWSZE TRENDY W OCHRONIE DZIEDZICTWA KULTUROWEGO WEDŁUG ZASAD ZRÓWNOWAŻONEGO ROZWOJU

Abstract

Preserving cultural heritage and ensuring its sustainable development, especially in the conditions of armed conflicts or natural disasters, requires certain efforts and the involvement of the latest technologies. The use of laser 3D technologies and drones to survey monuments and create their virtual models is a method for their preservation and research. The new technologies are used not only for the physical preservation of cultural heritage, but also for its adaptation. Adaptive reuse is a method of renewing objects that need rethinking and identity change, for example, Soviet-era buildings. The issues of thermal insulation of historical buildings and the use of solar energy are important. Modern energy modernization of monuments is aimed at a new approach to energy production and consumption.

Keywords: cultural heritage, principles of sustainable development, innovative technologies, energy efficiency, recycling, adaptive reuse

Streszczenie

Zachowanie dziedzictwa kulturowego i zapewnienie jego zrównoważonego rozwoju, zwłaszcza w warunkach konfliktów zbrojnych czy klęsk żywiołowych, wymaga pewnych wysiłków i zaangażowania najnowszych technologii. Wykorzystanie technologii laserowych 3D i dronów do inwentaryzacji zabytków i tworzenia ich wirtualnych modeli jest metodą ich konserwacji i badań. Nowe technologie są wykorzystywane nie tylko do fizycznej konserwacji dziedzictwa kulturowego, ale także do jego adaptacji. Adaptacyjne ponowne wykorzystanie jest metodą odnawiania obiektów, które wymagają przemyślenia i zmiany tożsamości, na przykład budynków z czasów radzieckich. Ważne są kwestie termoizolacji zabytkowych budynków i wykorzystania energii słonecznej. Nowoczesna modernizacja energetyczna zabytków ma na celu nowe podejście do produkcji i zużycia energii.

Słowa kluczowe: dziedzictwo kulturowe, zasady zrównoważonego rozwoju, innowacyjne technologie, efektywność energetyczna, recykling, adaptacyjne ponowne wykorzystanie

1. INTRODUCTION

Preservation and improvement of cultural values belong to the priority areas of state policy in the field of culture.

Losses of cultural values, immovable heritage, historical appearance of cities are irreversible and irreparable. Any loss of cultural heritage inevitably reflects on current and future generations,

leading to spiritual begging, falsification of history, loss of historical memory, destruction of the intellectual and creative potential of society as a whole. They cannot be compensated either by the creation of new significant works or by the development of culture as a whole.

The European Union (EU) has developed its framework for safeguarding cultural heritage, which covers the tangible, intangible and digital aspects of heritage, including memory, understanding, identity, dialogue, cohesion and creativity. The European framework for Action on Cultural Heritage, announced in the new European Agenda for Culture, is aligned with the Council of Europe's European Heritage Strategy and based on five pillars:

- cultural heritage for an inclusive Europe: participation and access for all;
- cultural heritage for a sustainable Europe: smart solutions for a cohesive and sustainable future;
- cultural heritage for a resilient Europe: safeguarding endangered heritage;
- cultural heritage for an innovative Europe: mobilising knowledge and research;
- cultural heritage for stronger global partnerships: reinforcing international cooperation[1].

Preservation of cultural heritage is a task for humanity, spanning both the past and the future, integrating technological advances with the preservation of the treasures of the past.

For this reason, heritage requires significant efforts to record, maintain, preserve and ensure its sustainable development. The use of new technologies to protect and quickly restore these unique works is especially important when they become a target for terrorists or when an armed conflict breaks out.

The policies of most post-Soviet countries did not favor the priority preservation of authentic architectural monuments, moreover, objects of cultural heritage were consistently and relentlessly destroyed, gradually being replaced by fakes, kitsch innovations or commercial new buildings. Thus, ten years ago in Ukraine, 50–70% of objects of historical and cultural heritage were in an unsatisfactory technical condition, up to 10% were in emergency condition[2].

This number grew tens or hundreds of times after the beginning of the full-scale invasion of Russia into Ukraine, which became a direct threat both to the lives of the people and to the historical and cultural heritage of Ukraine[3].

The Hague Convention of 1954 obliged the countries participating in the armed conflict to protect cultural heritage with the so-called "Blue Shield". This convention stipulates that in the event of hostilities, objects of cultural heritage cannot be either intentional targets or collateral victims of hostilities or bombings. According to the Hague Convention, "damage to cultural property belonging to any people means damage to the cultural heritage of all mankind, since each person contributes to the culture of the world."[4]. However, during the last 50 years of war in Bosnia, Sarajevo, Serbia, Macedonia, Syria, Ukraine, Israel, ignoring the Hague Convention, caused and continues to cause irreparable damage to the state of cultural heritage[5].

---

[1] Strategic framework for the EU's cultural policy [in:] Culture and Creativity, https://culture.ec.europa.eu/policies/strategic-framework-for-the-eus-cultural-policy (access: 1.10.2024).

[2] O. Oliynyk (ed.), *Concept of National Policy on Cultural Heritage Development in Ukraine (draft)*, Arkhitektura I Prestizh, Kyiv 2014, p. 14.

[3] V. Nazarenko, *872 cultural heritage sites suffered from Russian military aggression in Ukraine* [in:] Russia's war in Ukraine: official website, 12.01.2024, https://war.ukraine.ua/war-news/872-cultural-suffered-russian-military-aggression (access: 1.10.2024).

[4] I. Kasyanenko (ed.), *Mizhnarodni zasady okhorony nerukhomoi kulturnoi spadshchyny* [*International principles of immovable cultural heritage protection*]. Zbirnyk mizhnarodnykh normatyvnykh dokumentiv – Collection of international regulatory documents, Feniks, Kyiv 2008 [in Ukrainian].

[5] P.M. Sällström et al. (eds), *Future Images Ukraine. Proceedings from four seminars with Ukrainian*

At the same time, the loss of cultural values is irreversible and irreparable, they inevitably reflect on current and future generations, leading to spiritual begging, falsification of history, loss of historical memory, destruction of the intellectual and creative potential of society as a whole. They cannot be compensated either by the creation of new significant works or by the development of culture as a whole[6].

Thus, today the question arises not only about the preservation and adaptation of cultural heritage, but also about measures for its mass restoration, inventory and documentation of losses. This requires the involvement of the latest survey and research technologies, especially in the conditions of destroyed or damaged monuments.

The latest technologies in restoration, construction and surveying methods are considered today mainly from the angle of sustainable development. These are energy-saving, recycling technologies, or those that use natural and local materials, involving local industry and existing traditions. These are also the latest methods of examination, 3D scanning, digitization and determination of damage.

The connection of the technological industry with the principles of sustainable development is particularly relevant today, when the construction industry has become one of the most expensive of all production industries. Therefore, there is a trend in the world to reduce energy consumption and build facilities that provide themselves with renewable energy.

Requirements for improving energy efficiency in cultural heritage buildings establish the use of general principles of restoration, including reversibility and non-invasive interventions in historic buildings.

The ultimate goal of these conservation efforts is to promote the development of more ecologically sustainable and livable urban settlements while ensuring the preservation of the historical and cultural context[7].

2. FINDINGS

During destructive wars, when unique historical buildings are turned into ruins every day, a preventive policy of surveying the historical and cultural heritage and using various technologies for its preservation is necessary, which will help preserve the history of each country.

2.1. 3D SCANNING AND EXAMINATION TECHNOLOGIES

The development of certain technologies is a powerful tool in the fight against the disappearance of cultural heritage. Virtual reality allows the creation of interactive digital models of buildings, monuments and other heritage sites. Laser scanners are sometimes used to create highly accurate 3D digital models of buildings, monuments and other surviving heritage sites.

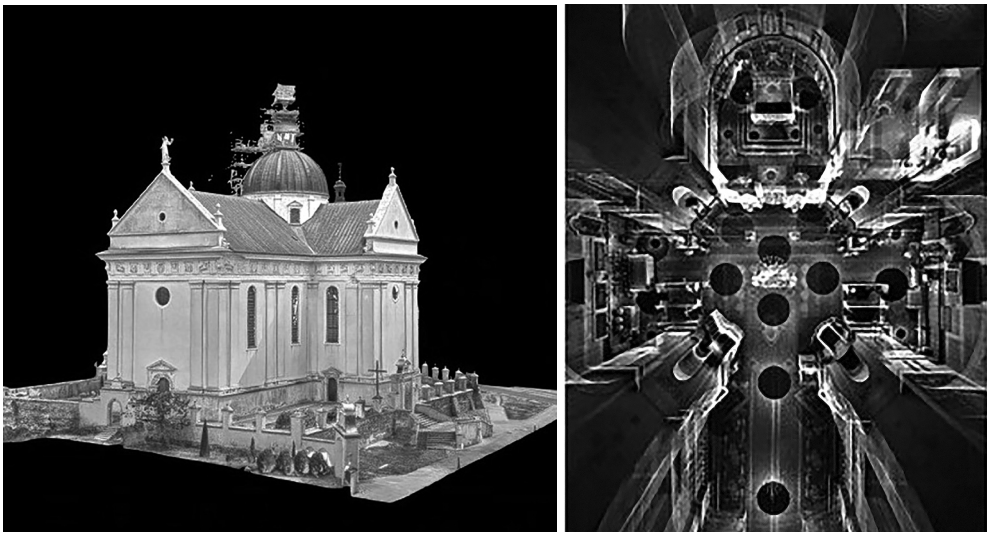
---

and Swedish architects during 2022–2023, Architects Sweden and National Union of Architects of Ukraine 2024, https://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-342707 (access: 1.10.2024).

[6] O. Oliynyk (ed.), *Concept of National Policy*, *op. cit.*, p. 14.

[7] L. Chen, X. Chen, L. Lang, *Building Information Protection Method of Urban Historical Features Based on BIM Technology*, "Advances in Multimedia" 2022, no. 1, art. no. 8998225. DOI: 10.1155/2022/8998225 (access: 1.10.2024); F. Cinquepalmi, V.A. Tiburcio, *Sustainable Restoration of Cultural Heritage in the digital era*, "VITRUVIO – International Journal of Architectural Technology and Sustainability" 2023, no. 8(2), pp. 76–87. DOI: 10.4995/vitruvio-ijats.2023.20545 (access: 1.10.2024).

In Ukraine, laser scanners are used to create digital models of monuments that are under threat of destruction, dilapidated or inaccessible. (Ill. 1).

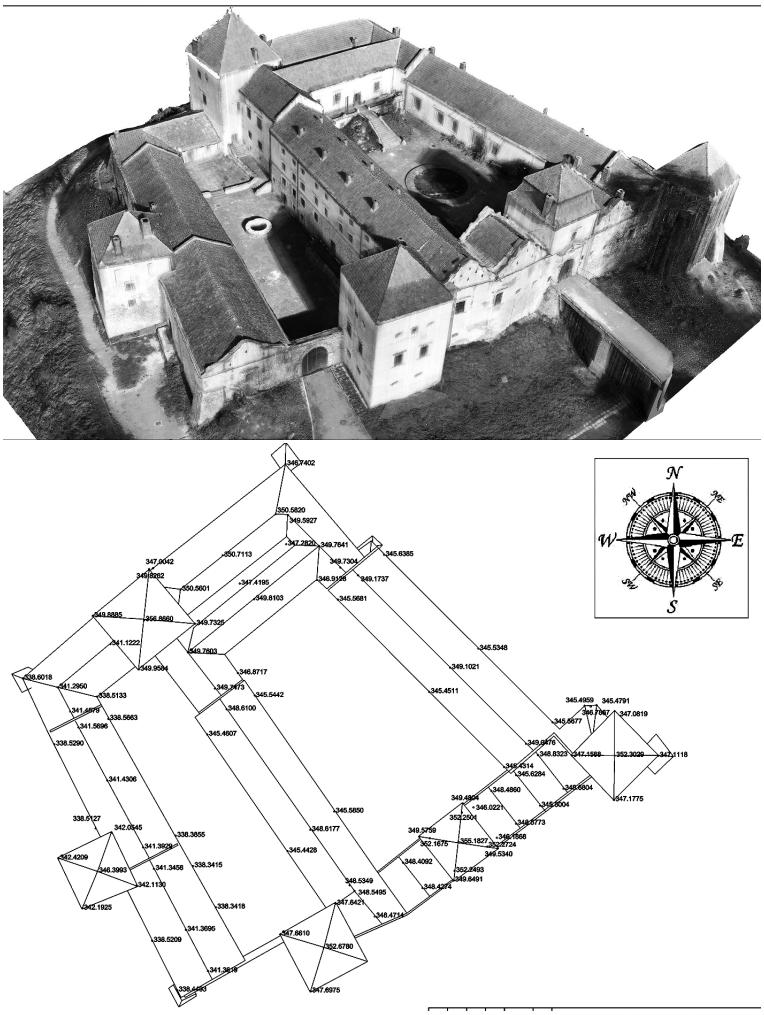


Ill. 1. Digitalization of cultural heritage objects in Ukraine: The Church of St. Lawrence in Zhovkva (1618) and the Church of St. Archangel Michael in Pidberiztsi (1891–1910). Digitalizing: Lviv company "Skeiron", 2022, source: https://skeiron.nira.app/a/CbC8cJzGTemFo_5NOOK0Qg/2.

Ill. 2. The scanning materials also helped the Department of Architecture and Urban Planning at the Lviv regional state administration to add the church of Saint Archangel Michael with its sacred paintings by Modest Sosenko to the List of newly discovered objects of the cultural heritage of the Lviv region, source: https://skeiron.nira.app/a/lC673BByS5adbBUjF1rg6A/1.

Terrestrial laser scanning is currently the only method that allows at high speed (hundreds of thousands of points per second) to determine the coordinates of a significant number of points on the object's surface with an accuracy from a few millimeters to 4 cm without significant surface distortions. The data obtained as a result of laser scanning allows you to fully reproduce any object in the form of a point 3D model.

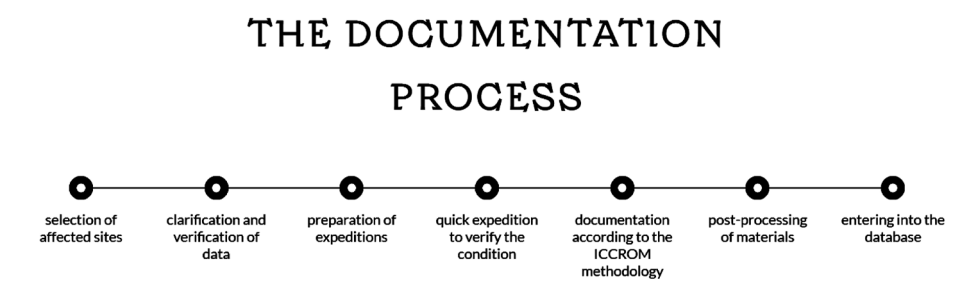
Drones that take aerial photos of monuments and archaeological sites are also used to create 3D models and topographic maps. Using ultra-high-resolution aerial imagery, photogrammetry combines information obtained from UAVs with powerful GIS mapping systems to create dynamic, measurable documents for a range of real-world situations and purposes.



Ill. 3. Works on creating a detailed digital orthophoto plan of the roof of the Svirzh Castle, geodetic engineer: D.V. Khomushko, source: Svirzh Castle, *op. cit*.

In 2018, the National Union of Architects of Ukraine developed "Svirzh Castle: Genesis. Development of the concept of revitalization and adaptation of the Castle in the village Svirzh

of the Peremyshlyan district of the Lviv region" (scientific supervisor O. Oliynyk), within the framework of which work was carried out on the creation of a detailed digital orthophoto plan of the roof of the Svirzh castle. A digital orthophoto plan of the roof and sections of the 3D model of the castle in planes under different azimuths were created. The works were carried out using geodetic determination methods using the latest technologies and modern equipment[8].



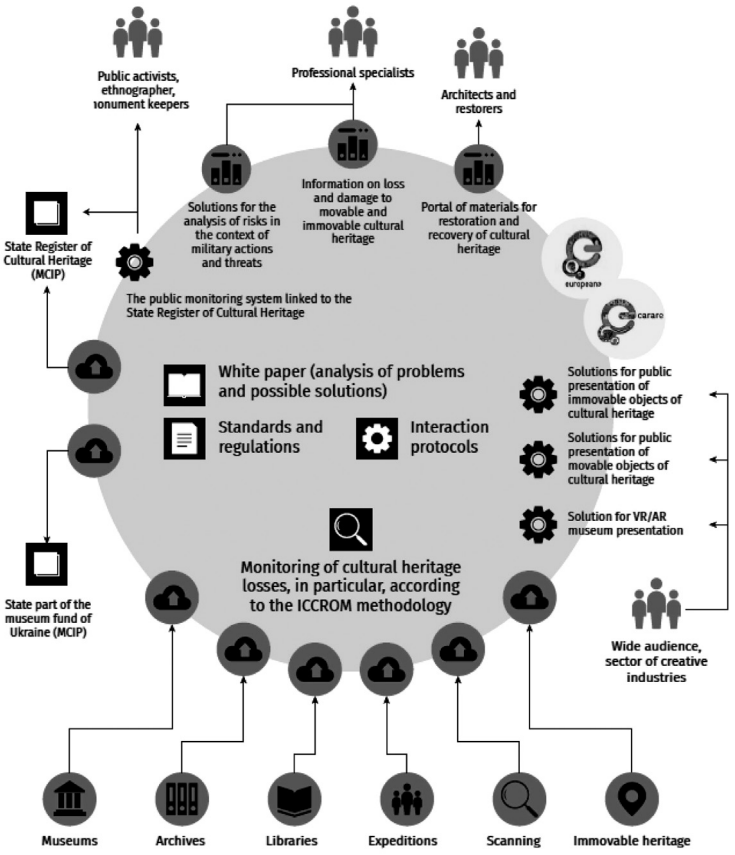
Ill. 4. The documentation processes, source: HeMo, https://www.heritage.in.ua/en (access: 1.10.2024).

Ill. 5. Church of the Nativity of the Holy Mother of God, Viazivka village, Zhytomyr region: general view, photogrammetry (May 2023), Laser scanning (October 2023). Vasyl Rozhko, source: V. Rozhko et al., *Heritage monitoring for restoration…*, *op. cit*., p. 17.

[8] Svirzh Castle: Genesis. Development of the concept of revitalization and adap-tation of the Castle in the village. Svirzh of Peremyshlyan district of Lviv region, No. 1188 of 09/21/2018 between the Ukrainian Cultural Fund and NSAU, NSAU, Kyiv 2018.

3D technologies are also used in Ukraine by the companies HeMo and Backup Ukraine, which document and digitize damaged objects with absolute accuracy immediately after the destruction, while they still exist. This methodology is somewhat unique, because never before was the documentation of losses carried out during a war, only a year and a half after its end, as in Sarajevo.[9]

The availability of digital cultural heritage will help record history, create a digital library for researchers and public education, and enrich social and cultural experiences (Ill. 6).



Ill. 6. Data infrastructure, source: V. Rozhko et al., *Heritage monitoring for restoration…*, *op. cit.*, p. 15.

Research and preservation of wooden churches is also carried out in Ukraine with the involvement of modern technologies. On the territory of the Lviv region there are more than four hundred sacred wooden monuments that need special protection. In addition to ongoing preservation measures, updating existing and creating new graphic materials is a particularly pressing issue. Today, ground-based laser 3D scanning is considered the most advanced digitization method with high accuracy.

[9] V. Rozhko et al., *Heritage monitoring for restoration. Report on the results of projects documenting the loss of cultural heritage*, Lviv-Kiyv-Kharkhiv 2023, https://cdn.prod.website-files.com/644845b6dd145f5c8abbd7c6/64d0c14ceca3ff02fd61cc61_hemo%20report%202023%20(2)%20eng%20roz.pdf (access: 1.10.2024).

During 2012–2015, a project was conducted on the territory of the Lviv region to scan wooden churches. The project was carried out in accordance with the Regional Program for the Preservation of Monuments of Wooden Sacred Architecture of the Lviv Region and was implemented by the Institute of Geodesy of Lviv Polytechnic University[10] (Ill. 7).

Ill. 7. Digital model of the wooden church Pr. Mother of God in the village Velikopole of Yavoriv district. Church scanning process, source: *3D scan of the wooden churches of Lviv region*, *op. cit.*

The latest technologies penetrate even into traditional methods of restoration. By definition, the main requirements for materials used during restoration work on cultural heritage sites are as follows: restoration materials must be close in physical, chemical, technical, and optical characteristics to the authentic materials of the monument; not to contribute to the destruction of the authentic existing decoration of the planes, especially painting; do not change the steam, moisture permeability and temperature regime of the premises; the strength of the restoration systems must be lower than the strength of the front surface of the authentic masonry (solutions)[11].

From the updated list of materials that are used in practice today, and differ from the list of those that were used in the middle of the 20th century and could be used by restorers at cultural heritage sites, can be attributed to: water-based bituminous waterproofing; system of sanitizing plasters; thixotropic cleaners that work on vertical planes (do not slide); ready solutions for reprofiling stone and brick masonry (but their main drawback is high strength); paint systems with a bionic principle of action (self-cleaning ability); a wide range of pigments for painting restoration.

Materials such as tow, olifa, clay lock arrangement are almost no longer found in technologies.

The latest technologies sometimes are used to "age" or preserve the "ruined" condition of facades, as, for example, in the renovation project of the neglected landmark of the Cassina Innovation House in Brazil, where thorough restoration work (cleaning, stabilization,

[10] *3D scan of the wooden churches of Lviv region* [in:] Geoterrace Network, https://geoterrace.lpnu.ua/en/3d-scan-wooden-churches-lviv-region (access: 1.10.2024).

[11] I. Kasyanenko (ed.), *Mizhnarodni zasady...*, *op. cit.*

consolidation, protection, etc.) were carried out to fix the condition of the facade made of authentic pigmented plaster with red sandstone powder[12].

Ill. 8. Renovation project of the abandoned landmark of the Cassina Innovation House in Brazil. The "shabby" condition of the facade has been preserved, source: H. Abdel, *Cassina Innovation House…*, *op. cit.*

2.2. ADAPTIVE REUSE

An important place in the implementation of the latest technologies based on the principles of sustainable development in heritage preservation is occupied by adaptive reuse. The question of the possibility and expediency of reproductions of historical and cultural heritage everywhere in the world is the most difficult ethical problem. The question of what is more important – the authentic appearance or the authentic remains – remains, as a rule, at the discretion of restorers[13].

But in Ukraine, the trends of destruction of authentic immovable heritage have reached such a critical level, which will be followed by the irreversible destruction of the traditional nature of the environment of historical cities, the loss of self-identification of the multinational culture of Ukraine, as well as a sharp decrease in the attractiveness of the state at the international level[14].

[12] H. Abdel, *Cassina Innovation House / Laurent Troost Architectures* [in:] ArchDaily, 9.03.2021, https://www.archdaily.com/958199/cassina-innovation-house-laurent-troost-architectures (access: 1.10.2024).
[13] O. Oliynyk (ed.), *Concept of National Policy...*, *op. cit*., p. 45.
[14] *Ibidem*, p. 46.

The way to find a certain compromise can be the method of adaptive transformation, which can be used in the case of restoration of damaged objects that are not the most valuable or objects that require re-interpretation and change of identification, as with the buildings of the Soviet period.

Adaptive reuse can be defined as the process by which an unused or inefficient element is transformed into a new element that can be used for another purpose. This architectural redesign is a consequence of the need to save energy in the production of building materials – one of the most energy-intensive and polluting industries[15].

This trend is consistent with three goals of sustainable development: responsible consumption, energy efficiency and urban development.

In Ukraine, to assess the losses and determine the value of buildings that are not recognized heritage sites for the purpose of their further adaptive transformation, within the framework of the EU UREHERIT grant program, Danish and Italian technologies based on the principles of sustainable development are involved.

Issues of national identity, as a guarantee of continuous and subsequent development, are closely related to the Sustainable Development Goals, as defined in[16].

Modern trends, such as eco-urbanism, green planning, ecological planning, bioclimatic urbanism, which indicate the need to radically change urban life in accordance with the sustainable city model, also directly affect historical cities.

Ill. 9. Reconstruction of the Tonofenfabrik brick factory into a museum (Lahr, Germany). The existing part of the building has been renovated, supplemented by a new stair tower made of red concrete, source: M.F. González, *Museum Tonofenfabrik Lahr / Heneghan Peng Architects* [in:] ArchDaily, 3.09.2018, https://www.archdaily.com/901070/museum-tonofenfabrik-lahr-heneghan-peng-architects (access: 1.10.2024).

Another source of renovation of historic cities is their abandoned industrial complexes, which in some places are not used for their intended purpose due to their obsolescence and/or high level of pollution and thus become available for reuse[17].

[15] A. Cedeño Valdiviezo, *Adaptive reuse: Its potential role in sustainable architecture and its relationship with restoration and rehabilitation*, "Revista de Arquitectura" 2023, no. 25(1), pp. 173–189. DOI: 10.14718/revarq.2023.25.4520 (access: 1.10.2024).

[16] P.M. Sällström et al. (eds.), *Future Images Ukraine…*, *op. cit*.

[17] S. De Gregorio, M. De Vita, P. De Berardinis, L. Palmero & A. Risdonne, *Designing the sustainable*

2.3. CIRCULAR ECONOMY. RECYCLING

The circular economy considers materials as assets that need to be stored rather than constantly consumed, thus contributing to sustainable development[18].

As an alternative to the linear economy, the circular economy represents a development strategy in the direction of sustainable growth, which is based on reducing the consumption of resources, increasing the useful life of products and using over consumption.

In 2020, the European Union published the Circular Economy Action Plan, which proposed requirements for the content of recycled waste in construction projects. This became a significant change in the paradigm of building regulations[19]. Currently, efforts to introduce recycled building materials are underway in Prague, where the municipal government has established "Reuse Centers" to collect and recycle old furniture and appliances, as well as household food waste for conversion into biogas.

One of the recent applications of the circular economy in construction is sustainable construction, which involves the use of environmentally friendly building materials. A product is environmentally compatible if it can be recycled at the end of its life[20]. For example, after the end of the life cycle of historical buildings, materials from them can be reused or recycled.

Another fundamental aspect of architectural decay restoration is the use of materials with low primary energy content, which do not pollute the environment and can be reused in the future or re-incorporated into the environment after decay. However, the use phase is the most significant in terms of energy consumption.

LCA (Life Cycle Analysis) allows for the selection of materials that can be easily separated at the end of the building's life, so that waste can be properly managed, in particular through recycling. Unlike recent buildings assembled using dry construction technology, which makes it relatively easy to reuse their parts, buildings built during previous centuries used glues and mortars to join materials together, making it extremely difficult to separate them later[21]. However, recycling most materials in historic buildings can be difficult.

Since historic architecture is generally built to last for centuries, it is sustainable architecture by definition sine qua non. The challenge is to achieve appropriate comfort conditions and reduce energy consumption in historic buildings.

2.4. FEATURES OF THERMAL INSULATION OF HISTORICAL BUILDINGS

The International Energy Agency (IEA) attributes more than 40% of heating and cooling energy savings under the low-carbon scenario to improved envelope structures[22].

When insulating enclosing structures, the outer location of the insulation layer is predominant. For historical buildings, the main and important disadvantage of such insulation is the loss of the historical appearance of the buildings.

---

adaptive reuse of industrial heritage to enhance the local context, "Sustainability" 2020, no. 12(21), art. no. 9059. DOI: 10.3390/su12219059 (access: 1.10.2024).

[18] N. Mossin (ed.), *An architecture guide to the UN 17 Sustainable Development Goals*, vol. 2, Royal Danish Academy – Architcture, Design, Conservation, Copenhagen 2020.

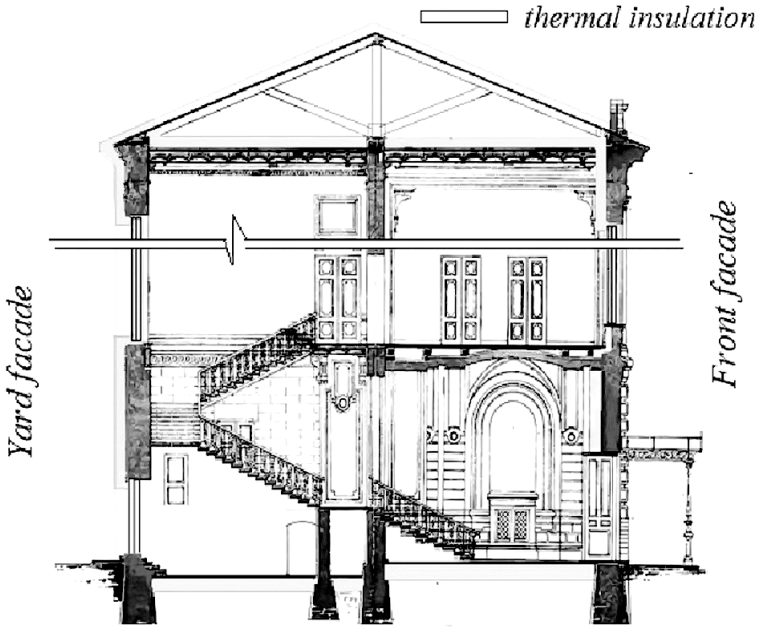
[19] A. Cedeño Valdiviezo, *Adaptive reuse…*, *op. cit*.

[20] *Ibidem*.

[21] *Ibidem*.

[22] International Energy Agency, *Technology Roadmap: Solar Photovoltaic Energy*, IEA, Paris 2014.

Therefore, it is better to abandon the insulation of the facades of historical buildings in favor of engineering re-equipment of the building. The threat of losing the authenticity of the historical environment (even of the usual background buildings) is incomparable in significance with insignificant energy savings. If the decision to insulate the facades is made, then a reasonable scheme can be the external insulation of the courtyard facades and the internal insulation of the front facades.[23] Current regimes of cultural heritage sites protection zones in most post-Soviet countries do not allow changes to the front facades of buildings, while courtyard facades can be changed. Penića, M. & Murgul V. propose the construction of internal insulation with the expectation of condensation. However, such a scheme is possible only in the absence of protected interiors[24] (Ill. 10).



Ill. 10. Scheme of insulation placement in a historic building, source: V. Murgul, V. Pukhkal, *Saving the Architectural…*, *op. cit*., p. 894

2.5. USE OF SOLAR ENERGY FOR THE PURPOSE OF ENERGY MODERNIZATION

Available today methods of increasing energy efficiency allow to reduce heat energy costs without harming the historical authenticity of residential buildings, this applies not only to facades, but also to the historical construction system of buildings. First of all, this is the technical re-equipment of the building (installation of energy-efficient devices and equipment).

[23] V. Murgul, V. Pukhkal, *Saving the Architectural Appearance of the Historical Buildings due to Heat Insulation of their External Walls*, "Procedia Engineering" 2015, vol. 117, pp. 891–899.

[24] M. Penića, S. Golovina, V. Murgul, *Revitalization of Historic Buildings as an Approach to Preserve Cultural and Historical Heritage*, "Procedia Engineering" 2015, vol. 117, pp. 888–895.

The evolution of architecture can be considered as a process of aesthetic mastering of new technical means, i.e. "transformation of the useful into the aesthetic." One of the important factors affecting the appearance of a modern building are elements related to the use of solar energy.[25]

The study of the global experience of using solar energy for the purpose of energy modernization of buildings – monuments of history and culture, made it possible to draw the following conclusions:

1) Making decisions about changing the appearance of historical buildings is based on an individual approach in each specific case and is coordinated with the authorities for the protection of historical and cultural monuments of this country.

2) Despite the fact that the states stand to protect historical buildings, it is the monuments of world importance that are often the bearers of the ideology of sustainable development. Modern energy modernization of unique buildings – monuments, often has as its goal not only and not so much the transition to energy supply based on renewable sources, but the idea of declaring the principles of a new energy policy, a new look at the processes of energy production and consumption.

3) Summarizing the existing global experience of energy modernization of historical buildings based on the use of solar energy, two main approaches can be distinguished:

– form-forming techniques, that is, visible and active methods of reconstruction: elements of solar energy supply are actively brought to the facade and dominate the updated form of the building,
– methods of inconspicuous modernization, which mask the methods of including solar energy supply systems in the exterior of the building, the principle of minimal intervention in the original appearance of the building is used.

4) Current regimes of protection zones of cultural heritage objects impose significant restrictions on the location of technological equipment directly on building structures. However, the level of development of PV-technologies today allows to make technological upgrading completely imperceptible. The conflict situation between the need to preserve the appearance of buildings and the use of solar energy can be avoided by using BIPV class solar elements integrated into the enclosing structures and window fillings, which provide masking techniques for technological retrofitting of the enclosing structures of buildings[26].

V. Murgul proposes to introduce the concept of temporary energy supply systems for additional energy supply systems based on solar energy. Building-independent temporary photovoltaics constructions (BITPVC), which can potentially be separated from the capital backbone of the building. The use of temporary energy supply systems allows to take into account the seasonality of fluctuations in the arrival of solar radiation, which is especially relevant in the climatic conditions of Ukraine and Kazakhstan, as well as to return to the original appearance of the historical building at any time[27].

---

[25] S. Baiani et al., *Integration of Solar Technologies in Historical Buildings: Construction of an Evolutionary Framework of Good Practices* [in:] A. Sayigh (ed.), *Mediterranean Architecture and the Green-Digital Transition*, Springer, Cham 2023, pp. 253–263. DOI: 10.1007/978-3-031-33148-0_21.

[26] F. Cumo et al., *La riqualificazione ambientale degli edifici storici: i tetti Verdi* [in:] *67° Congresso Nazionale ATI – Trieste, 11–14 Settembre 2012*, http://www.academia.edu/2421781/Redevelopment_of_historic_buildings_through_the_implementation_of_green_roofs_a_study_of_a_design_methodology (access: 1.10.2024).

[27] V. Murgul, *Solar energy systems in the reconstruction of heritage historical buildings of the north-*

Based on the study of the global experience of energy-efficient modernization of historical buildings of monuments of history and culture using solar energy, the main methods of integrating solar power systems into the enclosing structures of historical buildings were revealed, which can be combined into two groups: "masking" and "style-forming".

The first group includes solar power supply systems inconspicuously included in the enclosing constructions of buildings (for example, the BIPV class (Building-independent temporary photovoltaics constructions)) or the placement of solar equipment on invisible roof surfaces). The second group includes ideologically active methods of reconstruction, when solar equipment is openly placed on the facade of buildings, and is actually a new architectural dominant (solar systems of the BAPV class (Building attached photovoltaics systems) and methods of passive solar design[28].

BIPV solutions should be evaluated as opportunities in the energy efficiency processes of historic buildings. At the same time, it is necessary to assess the restrictions to mitigate the risks of impact on the architectural and landscape heritage, which is worthy and valuable.

Ill. 11. Implementation of photovoltaic systems on heritage buildings, source: F. Rosa, Building-Integrated Photovoltaics (BIPV) in Historical Buildings: Opportunities and Constraints, "Energies" 2020, no. 13(14), art. no. 3628. DOI: 10.3390/en13143628 (access: 1.10.2024).

3. CONCLUSION

Advanced technologies can help in the restoration and digitization of tangible cultural heritage.

This article presents projects and examples that have demonstrated significant progress in cultural heritage conservation. As these technologies continue to develop and experts in the field become more knowledgeable and skilled in the use of these technologies, there is a positive prospect that the continued improvement of technologies will provide further advances in cultural heritage preservation and digitization.

ern towns (for example Saint-Petersburg), "Journal of Applied Engineering Science" 2014, no. 12(2), pp. 121–128.

[28] F. Cumo et al., *La riqualificazione…*, *op. cit*.

The article examines the close historical connection between architectural restoration and the principles of sustainable development. Following the principles of environmental compatibility, new structures should be built in such a way that, when they are no longer needed, they can be disassembled and reused to avoid waste. However, achieving architectural sustainability in practice is still challenging, and architects and others involved in restoration must strive to balance historic authenticity with environmentally sustainable building and renovation practices.

References

[1] *3D scan of the wooden churches of Lviv region* [in:] Geoterrace Network, https://geoterrace.lpnu.ua/en/3d-scan-wooden-churches-lviv-region (access: 1.10.2024).

[2] Abdel H., *Cassina Innovation House / Laurent Troost Architectures* [in:] ArchDaily, 9.03.2021, https://www.archdaily.com/958199/cassina-innovation-house-laurent-troost-architectures (access: 1.10.2024).

[3] Baiani S. et al., *Integration of Solar Technologies in Historical Buildings: Construction of an Evolutionary Framework of Good Practices* [in:] Sayigh A. (ed.), *Mediterranean Architecture and the Green-Digital Transition*, Springer, Cham 2023, pp. 253–263. DOI: 10.1007/978-3-031-33148-0_21.

[4] Cedeño Valdiviezo A., *Adaptive reuse: Its potential role in sustainable architecture and its relationship with restoration and rehabilitation*, "Revista de Arquitectura" 2023, no. 25(1), pp. 173–189. DOI: 10.14718/revarq.2023.25.4520 (access: 1.10.2024).

[5] Chen L., Chen X., Lang L., *Building Information Protection Method of Urban Historical Features Based on BIM Technology*, "Advances in Multimedia" 2022, no. 1, art. no. 8998225. DOI: 10.1155/2022/8998225 (access: 1.10.2024).

[6] Cinquepalmi F., Tiburcio V.A., *Sustainable Restoration of Cultural Heritage in the digital era,* "VITRUVIO – International Journal of Architectural Technology and Sustainability" 2023, no. 8(2), pp. 76–87. DOI: 10.4995/vitruvio-ijats.2023.20545 (access: 1.10.2024).

[7] Cumo F. et al., *La riqualificazione ambientale degli edifici storici: i tetti Verdi* [in:] *67° Congresso Nazionale ATI – Trieste, 11–14 Settembre 2012*, http://www.academia.edu/2421781/Redevelopment_of_historic_buildings_through_the_implementation_of_green_roofs_a_study_of_a_design_methodology (access: 1.10.2024).

[8] De Gregorio S. et al., *Designing the sustainable adaptive reuse of industrial heritage to enhance the local context*, "Sustainability" 2020, no. 12(21), art. no. 9059. DOI: 10.3390/su12219059 (access: 1.10.2024).

[9] European Commission, *Communication From the Commision: A Roadmap for Moving to a Competitive Low Carbon Economy in 2050*, COM(2011) 112 Final, Brussels 2011.

[10] González M.F., *Museum Tonofenfabrik Lahr / Heneghan Peng Architects* [in:] ArchDaily, 3.09.2018, https://www.archdaily.com/901070/museum-tonofenfabrik-lahr-heneghan-peng-architects (access: 1.10.2024).

[11] International Energy Agency, *Technology Roadmap: Solar Photovoltaic Energy*, IEA, Paris 2014.

[12] Kasyanenko I. (ed.), *Mizhnarodni zasady okhorony nerukhomoi kulturnoi spadshchyny* [*International principles of immovable cultural heritage protection*]. Zbirnyk mizhnarodnykh normatyvnykh dokumentiv – Collection of international regulatory documents, Feniks, Kyiv 2008.

[13] López C.S.P., Frontini F., *Energy Efficiency and Renewable Solar Energy Integration in Heritage Historic Buildings*, "Energy Procedia" 2014, vol. 48**,** pp. 1493–1502. DOI: 10.1016/j.egypro.2014.02.169 (access: 1.10.2024).

[14] Mossin N. (ed.), *An architecture guide to the UN 17 Sustainable Development Goals*, vol. 2, Royal Danish Academy – Architcture, Design, Conservation, Copenhagen 2020.

[15] Murgul V., Pukhkal V., *Saving the Architectural Appearance of the Historical Buildings due to Heat Insulation of their External Walls*, "Procedia Engineering" 2015, vol. 117, pp. 891–899.
[16] Murgul V., *Solar energy systems in the reconstruction of heritage historical buildings of the northern towns (for example Saint-Petersburg)*, "Journal of Applied Engineering Science" 2014, no. 12(2), pp. 121–128.
[17] Nazarenko V., *872 cultural heritage sites suffered from Russian military aggression in Ukraine* [in:] Russia's war in Ukraine: official website, 12.01.2024, https://war.ukraine.ua/war-news/872-cultural-suffered-russian-military-aggression (access: 1.10.2024).
[18] Oliynyk O. (ed.), *Concept of National Policy on Cultural Heritage Development in Ukraine (draft)*, Arkhitektura I Prestizh, Kyiv 2014.
[19] Penića M., Golovina S., Murgul V., *Revitalization of Historic Buildings as an Approach to Preserve Cultural and Historical Heritage*, "Procedia Engineering" 2015, vol. 117, pp. 888–895.
[20] Rosa F., *Building-Integrated Photovoltaics (BIPV) in Historical Buildings: Opportunities and Constraints*, "Energies" 2020, no. 13(14), art. no. 3628. DOI: 10.3390/en13143628 (access: 1.10.2024).
[21] Rozhko V. et al., *Heritage monitoring for restoration. Report on the results of projects documenting the loss of cultural heritage*, Lviv-Kiyv-Kharkhiv 2023, https://cdn.prod.website-files.com/644845b6dd145f5c8abbd7c6/64d0c14ceca3ff02fd61cc61_hemo%20report%202023%20(2)%20eng%20roz.pdf (access: 1.10.2024).
[22] Sällström P.M. et al. (eds.), *Future Images Ukraine. Proceedings from four seminars with Ukrainian and Swedish architects during 2022–2023*, Architects Sweden and National Union of Architects of Ukraine 2024, https://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-342707 (access: 1.10.2024).
[23] Strategic framework for the EU's cultural policy [in:] Culture and Creativity, https://culture.ec.europa.eu/policies/strategic-framework-for-the-eus-cultural-policy (access: 1.10.2024) .
[24] Svirzh Castle: Genesis. Development of the concept of revitalization and adap-tation of the Castle in the village. Svirzh of Peremyshlyan district of Lviv region, No. 1188 of 09/21/2018 between the Ukrainian Cultural Fund and NSAU, NSAU, Kyiv 2018.

Author's Note

Prof. Olena Oliynyk, PhD, DSc, Arch.

Architect, urbanist, editor, teacher and interior designer, Dr. of Sciences, Professor at Faculty of Architecture, National Academy of Fine Arts and Architecture, Vice-President of the National Union of Architects, Head of the Ukrainian delegation at the Architectural Council of Europe, Corresponding member of the Academy of Architecture of Ukraine (since 1999), member of the Ukrainian National Committee of ICOMOS (UNESCO). UNESCO-UIA Architectural Education Commission & Validation Council Member (2014–2024), UIA WP Heritage and Cultural Identity Member. Founder and chief editor of the "Architecture and Prestige" magazine (1995–2008). Regional coordinator of the EU granted Projects: "Regional Cooperation for the Cultural Heritage Development" (2012–2014), "Architects for Heritage in Ukraine: Recreating Identity and Memory / U-RE-HERIT" (2023–2026). Her work involves design and research on both the architectural and urban planning scales, currently focusing on urban spaces, heritage preservation and historic cities development. She is an author of more than 20 urban development projects for the regeneration of historic city centres in Ukraine, the United States and Cabo Verde; many residential and public buildings. Worked as visiting professor at the Faculty of Architecture, Cracow University of Technology; Faculty of Architecture, Wroclaw University of Technology; Department of Construction, Architecture and Environmental Engineering, University of Zielona Gora (2024). Published as the editor and author of 42 professional full-colored "Architecture and Prestige", seven textbooks for Master's students and more than 200 articles in different research editions. Professional interests: Cultural Heritage Development, Urban Public Spaces, Spatial Analysis; Stylistics of Architecture of the 20th century, Interior Design, Architectural and Interior Design Education.

archiprestig@gmail.com