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(IM)PERMANENT DIGITAL HERITAGE AND 4D MODELING: EXPERIMENTAL ARCHITECTURE IN THE AGE OF ADAPTIVITY AND CIRCULARITY

(NIE)TRWAŁE DZIEDZICTWO CYFROWE A MODELOWANIE 4D: ARCHITEKTURA EKSPERYMENTALNA W DOBIE ADAPTACYJNOŚCI I CYRKULARNOŚCI

Abstract

In his design philosophy, Steven Holl introduces the concept of *forking times*, emphasising the fundamentally non-linear character of architecture as a network of divergent trajectories and speculative futures. Some of the most significant architectural accomplishments persist today only through photographs or engravings. *The Nakagin Capsule Tower* exemplifies an icon of experimental architecture that, despite its physical dismantling, endures in cultural memory and digital reconstruction. Contemporary digitisation technologies now enable the creation of photogrammetric models and Digital Twins of architectural heritage threatened by erasure. This article explores the tension between timeless architectural works preserved solely through documentation and ephemeral experiments that have become enduring components of the urban landscape. It also contributes to the broader discourse on the future of architectural heritage in the context of emerging paradigms such as *design for deconstruction*. Methodologically, the article adopts a contrastive approach to examine divergent trajectories in the formation of architectural objects. It juxtaposes material loss and digital permanence through the lens of contemporary 4D HBIM tools, enhanced by augmented reality (AR) and the Metaverse.

Keywords: architectural heritage, digital reconstruction, 4D BIM, 4D HBIM, speculative architecture

Streszczenie

W swojej filozofii projektowej Steven Holl wprowadza pojęcie "forking times" (rozwidlających się ścieżek), podkreślając nieliniowy charakter architektury jako sieci rozbieżnych trajektorii i spekulatywnych przyszłości. Niektóre z najwybitniejszych osiągnięć architektonicznych przetrwały do dziś jedynie w postaci fotografii lub rycin. Przykładem ikony architektury eksperymentalnej jest *Nakagin Capsule Tower* – obiekt, który mimo fizycznej rozbiórki nadal funkcjonuje w pamięci kulturowej i rekonstrukcjach cyfrowych. Współczesne technologie cyfryzacji umożliwiają tworzenie modeli fotogrametrycznych i cyfrowych bliźniaków (*Digital Twins*) dziedzictwa architektonicznego zagrożonego wyburzeniem. Artykuł przedstawia kontrast pomiędzy ponadczasowymi dziełami architektury zachowanymi wyłącznie w dokumentacji a efemerycznymi eksperymentami, które stały się trwałymi elementami krajobrazu miejskiego. Jest również głosem w dyskusji nad przyszłością dziedzictwa architektonicznego w kontekście nowych paradygmatów, takich jak projektowanie dla demontażu (*design for deconstruction*). Metodologicznie artykuł przyjmuje podejście kontrastywne, analizując rozbieżne ścieżki kształtowania obiektów architektonicznych. Zestawia materialną utratę z cyfrową trwałością, wykorzystując współczesne narzędzia 4D HBIM, rozszerzoną rzeczywistość (AR) i Metaverse.

Słowa kluczowe: dziedzictwo architektoniczne, rekonstrukcja cyfrowa, 4D BIM, 4D HBIM, architektura spekulatywna

1. INTRODUCTION

While designing the Institute for Contemporary Art (ICA) at Virginia Commonwealth University (VCU) in Richmond, Steven Holl based his design concept on a work by Argentinian writer Jorge Luis Borges. In the short story titled *The Garden of Forking Paths* (*El jardín de senderos que se bifurcan*), Borges presents a vision of reality in which all parallel, alternative versions of events occur simultaneously[1]. In his architectural reflections on art, Steven Holl introduces the concept of *forking times*, which reflects his design philosophy grounded in the pluralism of time and experience in both art and architecture[2]. The ICA building is a spatial reflection of Holl's creative thought – its four galleries can operate independently or in unison, allowing for the simultaneous coexistence of diverse experiences and interpretations of art. Alternative exhibition paths converge at a single point, the so-called *plane of the present* – a spatial plane of the present moment that connects the building's various functional zones[3]. The building also embodies the non-linearity and multi-threaded nature of design, where the final form is the result of a series of complex decisions. The parallel with Holl's creative approach and alternative visions of art and architecture served as a means to visualise the phenomenon of architectural heritage as a network of parallel trajectories. Architectural heritage can simultaneously be durable in the material sense – as a physical structure existing in time and space – and (im)permanent when understood as a digital record of an immaterial object.

Extending the analogy of parallel architectural paths, one can identify two further trajectories in the history of architecture: on the one hand, iconic architectural landmarks that no longer exist physically but have been preserved through digital documentation; on the other, structures originally conceived as short-lived architectural and construction experiments that, over time, evolved into lasting icons of their respective place and era (Ill. 1). Among the buildings emblematic of a particular epoch – whose demolition or destruction resulted in significant losses to architectural heritage – is *Pennsylvania Station* in New York (1910–1963). Its demolition provoked public outcry and ultimately led to the establishment of the *Landmarks Preservation Commission*[4], or the *Netherlands Dance Theater* (1987–2015), a postmodern landmark by OMA, which was completely demolished with little attention from the architectural press and minimal activist response, despite its significance as an iconic cultural venue and a pioneering work in contemporary theatre architecture[5]. One of the most prominent examples of an architectural disappearance is the story of the *Nakagin Capsule Tower* (1972–2022) in Tokyo. The building was thoroughly documented in digital form, and thanks to the efforts of the *Nakagin Capsule Tower Preservation and Restoration*

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[1] J.L. Borges, *The garden of Forking Paths*, Penguin Books, London 2018.

[2] *Newmarket Terrace. The plane of the present* [in:] Institute for Contemporary Art, https://icavcu.org/audio/arch_09/#:~:text=Holl%20often%20uses%20literature%20as%20inspiration%20for,different%20possibilities%20split%2C%20or%20fork%2C%20in%20time (access: 27.06.2025).

[3] *Institute for Contemporary Art, VCU* [in:] Steven Holl Architects, https://www.stevenholl.com/project/vcu-institute-for-contemporary-art/ (access: 27.06.2025).

[4] E.J. Plosky*, The fall and rise of Pennsylvania Station. Changing attitudes toward historic preservation in New York City*, Massachusetts Institute of Technology, [s.l.] 1999.

[5] A. Kats, *Amid zero protest, OMA's Netherlands Dance Theater meets its end* [in:] Metropolis, 4.04.2016, https://metropolismag.com/viewpoints/amid-zero-protest-oma-netherlands-dance-theater-meets-end/ (access: 27.06.2025).

Project, 23 out of 140 capsules were physically preserved. The structure itself has been meticulously transferred into the digital realm, ensuring its continued existence in virtual form despite the physical demolition[6]. In the history of Polish architecture, there are also numerous examples of buildings that were completely demolished due to structural, economic, or social reasons. Among them is one of the most significant examples of post-war Brutalism in Poland – the *Katowice Railway Station* (1971–2011)[7] as well as the modernist icon *Supersam* in Warsaw (1962–2006), known for its unique roof structure based on the *tensegrity system*, designed in part by Wacław Zalewski[8].

On the other side of architectural history are structures that were originally conceived as temporary architectural and structural experiments, yet ultimately became lasting fixtures embedded in the spatial and temporal context of their surroundings. This group is particularly associated with events such as World Expo exhibitions, which have served as platforms for experimental approaches to architecture and construction. Leading this list is the iconic and, at the time of its construction, highly controversial Eiffel Tower (1889), which permanently transformed the urban landscape of Paris (Ill. 2). The evolving digital realm offers new opportunities to document buildings threatened with demolition or subject to adaptive reuse. Hybrid technologies – such as photogrammetry and LiDAR – coordinated with the development of BIM models, make it possible to create highly detailed Digital Twins. BIM modelling, when extended to 4D BIM, allows for the addition of a temporal dimension to the 3D model, enabling the simulation of an object's lifecycle and technological scenarios over time. This capability opens new discussions about securing digital heritage even for structures designed according to principles of *Design for Deconstruction* and *Design for Disassembly* (DfD). Increasingly, the term HBIM (Historic Building Information Modelling) has become part of the architectural vocabulary. It functions not only as an analytical tool in heritage conservation but also as a method of conveying cultural narratives. Methodologically, the article adopts a contrastive approach to explore divergent trajectories in the formation of architectural objects. It juxtaposes material loss and digital permanence through contemporary HBIM tools combined with augmented reality (AR) and the Metaverse.

2. (NOT) ENDING LIKE NAKAGIN – ON ARCHITECTURE THAT NO LONGER EXISTS

The fate of the *Nakagin Capsule Tower*, designed by Kisho Kurokawa, had been under discussion since 2007, when the building's planned demolition was first publicly announced. Although the structure was ultimately dismantled in 2022, the decision was made in advance to create a digital archive that would preserve the cultural value of this iconic example of Japanese Metabolism. The *3D Digital Archive – Nakagin Capsule Tower project* was developed through a collaborative effort involving multiple partners. The coordination, strategy, measurements, and data distribution were managed by the Gluon team, while technical and

[6] Nakagin Capsule Tower, https://www.nakagincapsuletower.com/project (access: 27.06.2025).

[7] wolf, *11.1.11 – koniec Brutala z Katowic* [in:] BRYŁA, 13.01.2011, https://www.bryla.pl/bryla/1,85301,8936060,11_1_11___koniec_Brutala_z_Katowic. (access: 27.06.2025).

[8] WG, *Supersam w Warszawie – najnowocześniejszy pawilon handlowy* [in:] BRYŁA, 15.04.2024, https://www.bryla.pl/supersam-w-warszawie-najnowoczesniejszy-pawilon-handlowy-zapomniane-klisze (access: 27.06.2025).

academic oversight was provided by Professor Keisuke Toyoda (University of Tokyo) and Professor Mitsuhiro Kanada (Tokyo University of the Arts and Arup expert). In addition, several specialised partners were involved: Kumonos Corporation conducted the laser scanning; HoloLab was responsible for photogrammetry and AR/VR interface development; Shosaku Ohtonari (Fukuoka University) provided technical support for drone-based measurement control; and Arup Japan offered engineering and structural consultancy. The technological process involved LiDAR laser scanning, which generated a comprehensive point cloud of the entire building, capturing both the façades in their real state before demolition and the interiors. Simultaneously, photogrammetry was employed to produce over 20,000 high-resolution images using SLR cameras and drones. This technique enabled the mapping of realistic textures and the documentation of external structural transformations[9]. The project, led by Gluon, treats the moment of the Nakagin Capsule Tower's official demolition as a zero point, introducing a model of historical presence into the digital archive precisely at the building's final stage of operation. The group's efforts served as a form of cultural rescue, primarily focusing on capturing the building's surface through texture mapping onto a 3D point cloud, rather than creating a fully parametric model using BIM software.

The digital archiving of Nakagin became a substitute for architectural memory, offering access to its legacy to a broad audience and entering the realm of popular culture by enabling immersive interaction with the building in both AR and VR environments. This open-ended, narrative-driven experiment represents a new level of digital prevention against architectural oblivion.

Before the *Nakagin Capsule Tower* was constructed, another prominent figure of Japanese Metabolism, Kiyonori Kikutake, designed the *Miyakonojo Civic Center*, which was completed in 1966. For nearly 50 years, the building stood as one of the most important landmarks in Miyakonojo, located in the southern region of Kyushu Island. From the outset, it was a highly iconic multifunctional structure – an architectural hybrid serving both cultural and conference-related purposes. The conceptual foundation of the project envisioned future expansion; the building was intended to grow alongside the city, acting as a central meeting point for the local community. The life of the *Miyakonojo Civic Center* illustrates the tension between modernist heritage and the technical and economic realities of a contemporary city. Due to financial constraints and the absence of legal protection as a listed heritage site, the local authorities ultimately decided to demolish the building in 2019, despite opposition from the architectural community. Prior to its official dismantling, the Gluon team initiated a digital preservation project, integrating data from LiDAR laser scanning with photogrammetry comprising over 10,000 photographs. Following a methodology similar to that used for the *Nakagin Capsule Tower*, the Gluon team facilitated user interaction with the digital model through immersive access in both AR and VR environments (Ill. 3). The project was recognised at the 23rd Japan Media Arts Festival for challenging the material paradigm of architectural perception and extending it into the domain of XR reality[10].

Both the *Nakagin Capsule Tower* and the *Miyakonojo Civic Center* – relocated into the digital realm – become a form of *gamified experience*, aimed at deepening users'

[9] *3D Digital Archive – Nakagin Capsule Tower* [in:] gluon, https://gluon.tokyo/en/projects/3d-digital-archive-nakagin-capsule-tower (access: 27.06.2025).

[10] *3D Digital Archive – Miyakonojo Civic Center* [in:] gluon, https://gluon.tokyo/en/projects/3d-digital-archive-miyakonojo-civic-center (access: 27.06.2025).

emotional connection to a given place or architectural object through opportunities for self-directed exploration within the digital archive. Users can exchange memories, navigate 3D models in AR and VR environments, and engage with the content through a blend of education and play. In this context, the archive transcends the role of a static digital artefact and transforms into a quasi-living space – where the experience of architecture begins to resemble a game-like interaction in a virtual world, rather than a passive observation of a building.

3. TEMPORARY EXPERIMENTS THAT CHANGED THE HISTORY OF ARCHITECTURE

The history of architecture is rich with structures that were conceived as temporary, ephemeral installations or prototypes, yet have had a lasting impact on the development of architectural and construction technologies, urban planning, and design theory. Some of these structures have survived as physical artefacts, permanently altering the perception of their architectural context and serving as manifestos of their time and place. Others exist solely in digital form, yet still contribute to paradigm shifts in architectural thinking. Many such experimental projects were showcased during *World Expositions* (Expos), a tradition dating back to 1851 with the first *Great Exhibition in London*.

One of the defining characteristics of World Expositions for over 160 years has been innovation. These exhibitions serve as platforms for the evolution of architectural, structural, and functional typologies. Architectural and engineering innovations – as well as advancements in other disciplines reflective of their era – emerge across technological, scientific, intellectual, and artistic dimensions. Held in five-year cycles, Expo events bring together visitors from around the world and function as large-scale, innovation-driven global spectacles[11]. The topic of Expo remains highly relevant today, as the 2025 World Exposition is currently underway in Osaka under the theme: *Designing Future Society for Our Lives*. Expo has become a platform for presenting solutions that lie at the intersection of utopia and reality. Exactly 55 years ago, a historic Expo held in the same city – Expo'70 in Osaka – was among the most groundbreaking in terms of structural innovation for its time. Expo'70 featured pioneering pavilions such as the *U.S. Pavilion*, designed by David Geiger and Horst Berger, which showcased a pneumatic structure clad with a membrane; the *Fuji Group Pavilion* by Mamoru Kawaguchi and Yutaka Murata, then the world's largest pneumatic construction; and the *Takara Beautilion* by Kisho Kurokawa – a residential megastructure inspired in part by the ideas of the 1966 Archigram Network, led by Peter Cook. The latter became a conceptual precursor to the *Nakagin Capsule Tower*, foreshadowing a new direction in modular and Metabolist architecture[12].

One of the structures that permanently transformed the urban landscape of its city was the 300-metre-tall Eiffel Tower, built for the 1889 World Expo in Paris. The history of the tower is closely tied to a patent developed by Gustave Eiffel, Maurice Koechlin, and Émile Nouguier, titled *New device which facilitates the construction of metal columns and posts at a height of over 300 metres* from the year 1884[13]. Originally constructed as the entrance

[11] I.L. César, *World expos. A history of structures*, Architect Publications S.L., Barcelona 2017.
[12] *Ibidem*, pp. 505–507.
[13] *Ibidem*, p. 182.

gate for the Paris Expo of 1889, the Eiffel Tower was intended as a demonstration of France's engineering and technological prowess at the end of the 19th century. It was designed as a temporary structure with a projected lifespan of 20 years and was scheduled for dismantling in 1909. From the outset, the tower provoked intense debate and opposition, particularly from artistic and intellectual circles. Ultimately, it was preserved due to its strategic importance in telecommunications and later played a key role during World War I as a military radio transmitter. The Eiffel Tower went on to become a global symbol of modernity – a technological manifesto, an icon of art, literature, and popular culture. It validated the feasibility of steel lattice structures and established a new paradigm for industrial architecture, where structure itself becomes the aesthetic.

The *German Pavilion*, designed by Ludwig Mies van der Rohe and Lilly Reich for the 1929 Barcelona Expo, played a pivotal role in early 20th-century architectural history. Unlike the Eiffel Tower, its creation was met with widespread admiration from the artistic and architectural communities. The building's legacy includes its dismantling and subsequent reconstruction on the original site in 1986, based on original drawings and archival materials. The reconstruction was carried out with geometric precision, faithfully reflecting the pavilion's original aesthetic. This case highlights the critical importance of architectural documentation: it was the detailed drawings that enabled the high-quality re-materialisation of the structure's twin and the reactivation of the site as a cultural artefact[14].

Contemporary experimental realisations of ephemeral and temporary structures take on diverse forms – one example being a pneumatic structure in China, a 50-metre quasi-dome installed above a construction site in Jinan to protect nearby buildings and residents from construction-related pollution. Designing with temporariness in mind often leads to the paradox of temporary architecture becoming a bold experiment. Many such structures have attained the status of cultural symbols, technological manifestos, or prototype solutions for future architectural projects. Some experiments vanished without a trace, while others survive only as archival records. From the perspective of architectural heritage, this underscores the critical importance of reliably transferring architectural structures into the digital realm.

4. SCHRÖDINGER'S ARCHITECTURE: THE DIGITAL TWIN IN THE CONTEXT OF PRESERVING HISTORICAL AND FUTURE HERITAGE

In discussions on the application of digital solutions for the protection of architectural heritage, it is essential to include initiatives based on the use of artificial intelligence. One such example is HeritageWatch.AI, a non-profit organisation whose mission is to detect and report threats to, and destruction of, cultural and natural heritage through a platform that integrates historical archives, 3D modelling, and AI technologies. The platform was developed through collaboration between international organisations and technology companies, including Microsoft, ALIPH, Planet, and Iconem. Currently available reports include *Assessing the Impact*

[14] L.M.D. Guereñu, *The Sequence of Mies van der Rohe in Barcelona: the German Pavilion as Part of a much Larger Industrial Presence*, "Docomomo Journal" 2017, no. 56, pp. 56–63. DOI: 10.52200/56.A.UY5O2BW6.

of the Conflict on Gaza's Cultural Heritage (2023–2024) and *Impact of the TAPI Pipeline Project on Archaeological Sites in Afghanistan* (2023)[15].

Digital twins can also be employed to model time in the context of a building's lifecycle, including operation and potential future modifications or extensions. In current architectural nomenclature, tools based on 4D BIM and 4D HBIM are increasingly gaining relevance. Both approaches focus on representing temporal changes in buildings, yet they operate in opposite directions. 4D BIM modelling is oriented towards future transformations of a structure, enabling the development of scenarios and simulations of anticipated changes throughout a building's planned lifecycle. Each component of the structure is linked to information on its construction, installation, dismantling, and maintenance schedule. This form of digital recording brings multiple advantages, including visualisation of construction sequences, detection of potential structural conflicts, and maintenance planning integrated with the overall construction timeline. The development of BIM-based digital twins also involves the interoperability of geometric and semantic data, ensured through adherence to a variety of technical standards. One such international open standard for data exchange in BIM is IFC (Industry Foundation Classes), developed by buildingSMART International – an organisation dedicated to the standardisation, development, and dissemination of technological solutions for BIM data exchange (including IFC, BCF, and bSDD). Another key reference is ISO 19650, a standard that defines the framework for information management in BIM environments, including file naming conventions, data-sharing protocols, and the creation of a *Common Data Environment* (CDE)[16].

In contrast, 4D HBIM focuses on recording a building's past by integrating its historical chronology. Here, the fourth dimension is not the construction timeline but rather historical time – understood as a sequence of changes in the building's material, function, structure, and context over the course of its existence (Ill. 4). The 4D HBIM methodology provides parametric information that serves as a valuable tool in conservation practices. A digital twin in this context exists as a representation of an object that may still physically exist – or may not. This creates a certain ontological ambiguity: to what extent does a structure continue to exist when it is digitally preserved in its entirety but physically demolished?

The digital twin retains essential characteristics of the original building, including its geometry, materials, and functions. However, its existence is immaterial, blurring the line between existing heritage, simulated heritage, and imagined heritage. A notable example of HBIM modelling and the application of the scan-to-HBIM process is the Church of San Nicola in Montedoro. The process was divided into five key stages: 3D scanning and photogrammetry using TLS (terrestrial laser scanning); cleaning of the point cloud to reduce visual noise and distortion; parametric HBIM modelling; classification and categorisation of the data, including the assignment of LODs (Levels of Detail) and LOIs (Levels of Information); and, finally, the creation of a comprehensive documentation repository as a knowledge base for the site.

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[15] *AI and heritage renovation: when technology gives voice to the stones* [in:] Constructing a Sustainable Future by Saint-Gobain, 6.04.2025, https://www.constructing-sustainable-future.com/en/ai-and-heritage-renovation-when-technology-gives-voice-to-the-stones/ (access: 27.06.2025).

[16] ISO standard: *Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling, Part 1: Concepts and principles*, BS EN ISO 19650-1:2018.

In the case of heritage buildings, a significant portion of the model geometry consists of irregular forms, which considerably extends the modelling time and prevents the use of pre-existing BIM components. Such cases require a hybrid approach that combines laser scanning, photogrammetry, graphical data from archival drawings, and manual BIM modelling[17]. The 4D HBIM method is becoming increasingly precise and feasible, evolving from pilot projects to practical implementation. As such, 4D HBIM modelling can provide substantial support for long-term conservation strategies and serve as a preventive tool in heritage preservation.

5. DIGITAL TWIN AND GENIUS LOCI: TEXTURES, MATERIALS, AND SPACES

Architecture is not merely a building – it is also the experience of space and its embeddedness in context: the perception of scale, the encounter with materials and textures. Architecture extends far beyond geometric form or functional layout; it is a multidimensional experience of space, encompassing the perception of scale, light, materiality, sound, and the passage of time. It is inherently tied to the concept of *genius loci* – the spirit of place – which implies a relationship between a site and its material and immaterial cultural context. Following this perspective, the digital preservation of heritage is not limited to documenting form; rather, it engages with the emotional and symbolic dimensions of architecture. Digital heritage provides memory, methodology, and tools for representing the architectural object. The *speculative ontology* proposed by Quentin Meillassoux and Graham Harman seeks to transcend anthropocentric limitations in our understanding of the world, aiming to grasp the nature of things as they exist independently of human perception. According to Harman's Object-Oriented Ontology (OOO), a digital representation of a building is not merely a simulacrum – it constitutes, in a certain sense, an entity capable of acting upon and shaping the experience of place. In this light, digital architectural heritage can be understood as a processual presence – existing simultaneously in both the material and digital realms.

6. THE HERITAGE OF TOMORROW'S ARCHITECTURE – AR AND THE METAVERSE

Today, the architect may be viewed as a curator of alternative spatial visions. They no longer design solely physical structures but also shape narratives that directly influence the interpretation and perception of space. In an era shaped by circular design thinking – where concepts, such as *Design for Disassembly* (DfD)[18] and *Reversible Building Design*[19], have

[17] D. Constantino, M. Pepe, A.G. Restuccia*, Scan-to-HBIM for conservation and preservation of Cultural Heritage building: the case study of San Nicola in Montedoro church (Italy)*, "Applied Geomatics" 2023, no. 15, pp. 607–621. DOI: 10.1007/s12518-021-00359-2.

[18] E. Stricker et al. (eds), *Reuse in construction. A compendium of circular architecture*, Park Books, Zurich 2023.

[19] E. Durmisevic, *WP3 Reversible Building Design. Reversible Building design guidelines*, University of Twente 2018, https://www.bamb2020.eu/wp-content/uploads/2018/12/Reversible-Building-Design-guidelines-and-protocol.pdf (access: 27.06.2025).

become embedded in architectural discourse – the discussion surrounding historical heritage and the future of architecture enters an entirely new dimension. Does designing for disassembly, temporariness, and recycling constitute a conscious act of designing for impermanence, thereby contradicting the very notion of heritage? With today's digital tools, it is possible to record the history of an architectural object in ways that account for its lifecycle, structural migration across time and space, and alternative functional trajectories. This interpretation – linking dismantlable structures with 4D digital modelling – creates a space for architectural experimentation, which remains a fundamental and inseparable element of the design process.

Digital architectural heritage can also permeate the virtual realm in multifaceted ways. One example that embodies this approach is the project SteamRift – *Parowe Szczeliny* – presented during the Digital Cultures 2020: Imagined Futures festival, organised by the Adam Mickiewicz Institute in Warsaw in 2020[20]. Rafał Szrajber – the author of the project – is an architect and spatial researcher, and the creator of a theoretical framework for virtual heritage reconstruction. His work focuses on exploring virtual reality (VR) and augmented reality (AR) as narrative environments[21].

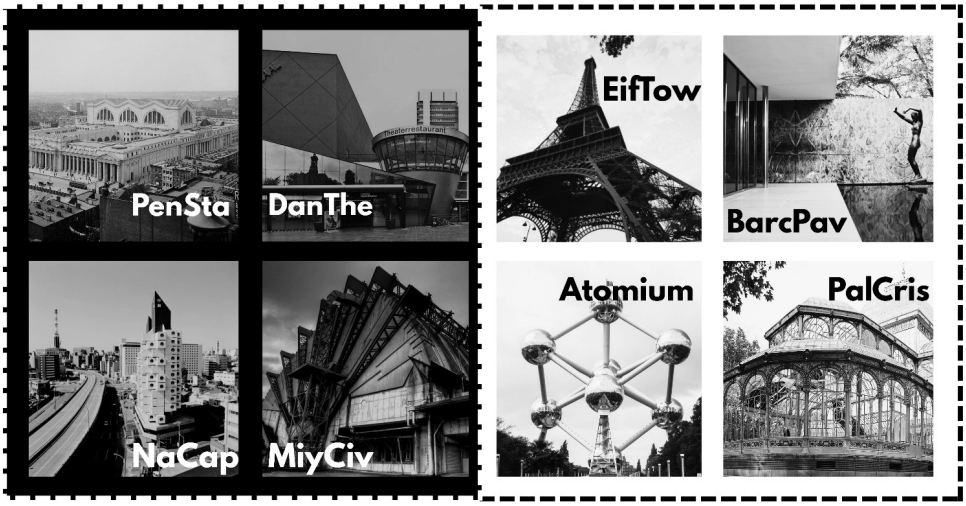
The transition into the digital realm can offer a means of preservation for many architectural heritage sites threatened by demolition, natural disasters, armed conflict, or structural degradation. Combining 4D BIM modelling with elements of AR and VR opens up new possibilities for experiencing architecture through virtual immersion. While such perception differs from the physical, embodied experience of architectural space – and cannot fully replicate it – it provides an alternative mode of engagement. Architecture becomes a medium of memory, its role expanding beyond functional solutions to encompass user perception, digital narrative, and the stewardship of cultural memory. When the architect assumes the role of cultural curator – moderating both the present and the future of a building – they reveal alternative development paths, wherein architecture transforms into a world of forking trajectories.

Ill. 1. Diagram illustrating two parallel trajectories of architectural heritage (author's own elaboration):

[20] P. Szrajber, *Parowe Szczeliny [SteamRift]* [in:] Digital Cultures 2020, https://www.asp.lodz.pl/index.php/pl/inne-wystawy/1767-parowe-szczeliny-steamrift-rafal-szrajber (access: 27.06.2025).

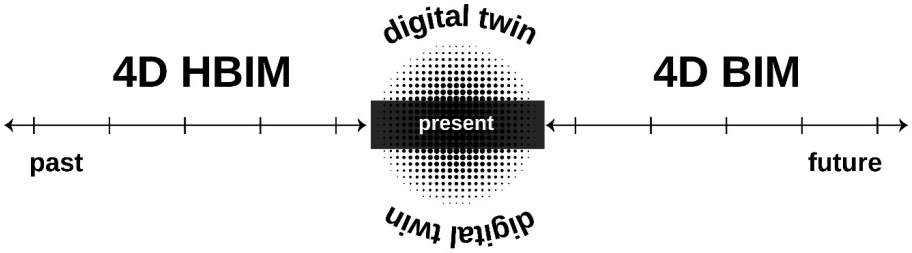
[21] *Ibidem*.

Architectural icons that now exist solely in the digital realm and temporary structures that have since become iconic landmarks, permanently reshaping the urban landscape



Ill. 2. A comparative visual composition presents two parallel narratives within architectural heritage. On a black background are structures such as Pennsylvania Station, the Netherlands Dance Theater, the Nakagin Capsule Tower, and the Miyakonojo Civic Center – buildings that once stood as defining symbols of their time, but whose demolition has resulted in significant cultural and architectural loss. In contrast, the white background features structures originally conceived as temporary architectural or engineering experiments, including the Eiffel Tower, the Barcelona Pavilion, the Atomium, and the Palacio de Cristal. Despite their intended impermanence, these buildings have become enduring icons, permanently embedded in the spatial and historical identity of their respective cities. Own elaboration

Ill. 3. Digitisation of the Miyakonojo Civic Center by Gluon, carried out as a digital preservation effort for a building at risk of demolition. The structure was transferred into the digital realm with the added potential for AR and VR integration, source: *3D Digital Archive – Miyakonojo Civic Center* [in:] gluon, https://gluon.tokyo/en/projects/3d-digital-archive-miyakonojo-civic-center (access: 13.07.2025)



Ill. 4. Diagram illustrating the developmental trajectories of 4D HBIM and 4D BIM in the context of digital twins, source: own elaboration.

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[1] *3D Digital Archive – Miyakonojo Civic Center* [in:] gluon, https://gluon.tokyo/en/projects/3d-digital-archive-miyakonojo-civic-center (access: 27.06.2025).

[2] *3D Digital Archive – Nakagin Capsule Tower* [in:] gluon, https://gluon.tokyo/en/projects/3d-digital-archive-nakagin-capsule-tower (access: 27.06.2025).

[3] *AI and heritage renovation: when technology gives voice to the stones* [in:] Constructing a Sustainable Future by Saint-Gobain, 6.04.2025, https://www.constructing-sustainable-future.com/en/ai-and-heritage-renovation-when-technology-gives-voice-to-the-stones/ (access: 27.06.2025).

[4] Borges J.L., *The garden of Forking Paths*, Penguin Books, London 2018.

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