School of Collectively Building
Proceedings Series 01.1

Sustainable Inside & Outside

SOCB
School Of Collectively Building

SOCB PROCEEDINGS SERIES 01.1

(SOCB) School of Collectively Building.

International Conference on **Sustainable Inside and Outside**

12-14 May, Vienna, Austria 2025

education & research

SOCB

school of collectively building

vienna - austria

EDITORS:
Moritz Elbert
Rasha Sukkarieh
Priya Mahendra Chavan
Sonali Dahotre
Santosh Kumar Ketham

PROOFREADING:
Dieter Soerensen

SOCB PROCEEDINGS SERIES 01.1

ISSN: 3061-032X, ISSN: 3061-0338

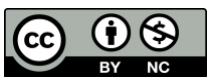


TABLE OF CONTENTS

INTRODUCTION

Sustainable Inside and Outside

As climate change accelerates with undeniable force, the spaces we inhabit, both inside and outside, are undergoing profound transformation and increasing vulnerability. Across the globe, cities are confronting overlapping crises that include extreme heat, water scarcity, flooding, pollution, biodiversity loss, and widening social inequities. These challenges are no longer distant forecasts but lived realities shaping everyday life. Clean air, fresh water, healthy food systems, safe shelter, accessible public spaces, and cultural continuity, once taken for granted, are now under threat. Urban environments in particular are burdened by congestion, noise, inefficient infrastructure, and development models that often prioritize short-term growth over long-term resilience and human well-being. In response to this moment of urgency, the International Conference on Sustainable Inside and Outside, held in Vienna in 2025, convened scholars, architects, planners, designers, educators, environmentalists, and policymakers from across the world. The conference was conceived not merely as an academic forum, but as a collective platform for reflection, responsibility, and action. It recognized sustainability as a multidimensional challenge that is environmental, social, cultural, and ethical, and emphasized the inseparable relationship between interior and exterior spaces, between buildings and cities, and between human environments and the natural world.

EDITORIAL NOTES

The theme Sustainable Inside and Outside resonates as both a conceptual framework and a guiding vision. It speaks to the continuity between private and public realms, between heritage and innovation, and between local identities and global challenges. International conferences of this nature play a vital role in shaping global discourse. They function as spaces of encounter and exchange where knowledge crosses disciplinary and cultural boundaries, shared challenges are confronted collectively, and new imaginaries for the future begin to take form. The contributions presented within this proceeding reflect this spirit of collaboration, interdisciplinarity, and urgency, offering diverse yet interconnected perspectives on how sustainable transformation can be achieved. Several of the papers foreground the importance of place-based approaches, particularly within small and medium-sized cities that often face structural disadvantages yet hold immense potential for meaningful change. Public spaces emerge as critical instruments for social cohesion, environmental resilience, and cultural continuity. When thoughtfully designed and inclusively governed, they become more than physical settings.

They act as catalysts for urban regeneration and as places of hope where communities gather, express identity, and reclaim agency. The research presented demonstrates that sustainable public spaces are most successful when shaped through participatory processes that involve local authorities, residents, researchers, and practitioners working collaboratively. Such approaches ensure that design solutions respond not only to technical and environmental criteria but also to lived experiences, historical layers, and collective aspirations. The proceedings also highlight the value of learning from vernacular knowledge and traditional building practices, particularly in regions facing extreme climatic conditions. In rapidly developing contexts such as the Arabian Peninsula, the loss of climate-responsive architectural traditions has resulted in energy-intensive housing models that are increasingly unsustainable. By revisiting indigenous dwelling typologies and integrating them with contemporary technologies, new forms of habitation can emerge that respect cultural values, reduce environmental impact, and foster self-sufficiency. These explorations remind us that sustainability does not lie in rejecting the past, nor in uncritically embracing modernization, but in carefully weaving together accumulated wisdom and technological innovation.

A recurring theme throughout the proceedings is the imperative to rethink demolition-driven development models. Nowhere is this more evident than in the discussion of public and educational buildings constructed during the mid-twentieth century. As countries commit to ambitious climate neutrality targets, the continued demolition of structurally sound buildings represents a significant environmental and cultural loss. Schools, in particular, hold a unique position as civic anchors that support learning, memory, and community life. The research presented advocates for a renovation-first approach grounded in life-cycle assessment, architectural valorisation, and participatory design. By extending the life of existing structures, cities can significantly reduce carbon emissions while preserving social continuity and spatial potential. The proceedings further expand the notion of sustainability into the digital realm, emphasizing that preservation is not limited to physical materials alone. As archaeological and heritage research increasingly relies on digital tools such as three-dimensional modelling and virtual reconstruction, questions of authenticity, transparency, and long-term value come to the forefront. The papers underscore those digital reconstructions gain meaning not simply through visual representation, but through the careful documentation of the interpretive processes behind them. Preserving contextual information, decision-making narratives, and methodological data ensures that digital heritage remains a credible and reusable form of historical knowledge for future generations.

Adaptive reuse emerges as a unifying strategy that bridges environmental responsibility with cultural stewardship and social equity. Across diverse international contexts, the reuse and retrofit of existing buildings are shown to significantly reduce embodied carbon, conserve resources, and activate underutilized urban areas. Beyond measurable environmental benefits, adaptive reuse supports economic regeneration, strengthens local identity, and contributes to more inclusive urban development. However, the proceedings make clear that realizing the full potential of adaptive reuse requires systemic support. This includes policy frameworks that prioritize whole-life carbon assessment, financial instruments that recognize cultural and social value, regulatory flexibility, and governance models that actively involve communities.

Taken together, the contributions in this proceeding affirm that sustainability is not a singular solution or discipline, but a relational process. It unfolds between inside and outside, between old and new, between technology and tradition, and between individual spaces and collective futures. Education, research, and international collaboration are central to this transformation. Universities, schools, non-governmental organizations, professional bodies, and local communities all play critical roles in shaping knowledge, fostering innovation, and translating ideas into action. The International Conference on Sustainable Inside and Outside serves as a reminder that the challenges we face are shared, and so too is the responsibility to respond. The tools, methodologies, and examples presented here demonstrate that alternative pathways are possible. These pathways are rooted in care, continuity, and collective imagination. The urgency is clear, the knowledge is growing, and the need for action is immediate. What remains is the sustained commitment to design, plan, and inhabit environments that are not only efficient and resilient, but also just, meaningful, and life-affirming for generations to come.

The Role of Adaptive Reuse in Achieving Sustainable Urban Futures

Author:
Dr. ASMA MEHAN

Affiliation:
HUCKABEE COLLEGE OF ARCHITECTURE, TEXAS TECH UNIVERSITY, USA

INTRODUCTION

Adaptive reuse has emerged as a transformative strategy to foster sustainability in urban development while conserving cultural and historical resources. This paper examines adaptive reuse in relation to sustainability, with particular emphasis on industrial heritage sites and their role in reimagining urban spaces. Cities are faced with the undeniable reality of the construction industry's significant contribution to global energy and emissions challenges approximately one-third of global energy consumption and CO_2 emissions.[1] This necessitates a far greater focus on climate strategies that preserve and extend the utility of existing buildings.[2] As noted by the International Energy Agency, operational energy expenditures on buildings account for about 30 percent of global energy spending, and when construction materials are included, the figure rises to 34 percent.[3] Additionally, the United Nations Environment

Program reports that combined CO_2 emissions from the operation and construction of buildings exceed one-third of total global CO_2 emissions.[4] Thus, there is a need to shift from development cantered on demolition toward reuse, retrofitting, and low-carbon design.[5] Adaptive reuse sidesteps the significant embodied carbon "upfront" footprint of new construction. Research shows that the reuse and retrofit of existing structures can offset 50-75% of carbon emissions compared to new construction.[6] Lifecycle analysis of a renovation project demonstrated a 37% reduction in total carbon emissions over 60 years compared to a code-compliant new build, and operational energy savings alone can offset the carbon penalty of renovation within two years.[7] Other studies report 68-78% embodied carbon reduction in adaptive reuse projects.[8] Through international case studies in Portland, Beijing, Shanghai, Amsterdam, London, and Cape Town, this paper integrates ecological, economic, and cultural aspects to frame policy. It proposes a governance strategy based on whole-life carbon assessment, multi-criteria decision analysis, and heritage policy to root adaptive reuse as the backbone of resilient and just urbanism.

1. Adaptive Reuse as an Engine for Sustainability

Cities all over the world face huge environmental pressures and the associated rising social inequities. The climate crisis and dwindling natural resources are confrontations that humanity Cities worldwide face environmental pressures and associated social inequities. The climate crisis and dwindling natural resources demand urgent action. Within this context, adaptive reuse counters environmental

pressures while protecting unique cultural identities that might otherwise be erased in favour of new construction. The city is as much an idea as it is a physical manifestation an engine of economic wealth creation, a cultural organism, and a home.[9] A “better urbanism” must integrate environmental, cultural, and socio-economic dimensions, which includes prioritizing reuse over demolition. In practical terms, it means not building new if not necessary and not burning anything if it can be avoided. Mission statements adopted by the "American lantern" and the virtues of the city which cover some 70,000 volumes make it clear: they intend to be a potent engine of the kinds of emissions that will not warm the Earth.

Reuse is strongly aligned with circular economy principles and is extremely beneficial from an environmental point of view. Instead of collapsing under a linear "take-make-discard" system, the adaptive reuse of historic buildings allows us to preserve natural and human resources, minimize waste, and make the most of the sunk costs and energy we've already invested in existing structures.[10] Current research confirms the not-so-surprising finding that as buildings improve in operational efficiency, the embodied carbon we put in them increasingly dominates the total environmental impact.[11] In fact, using resilient materials to construct climate-responsive buildings designed to last a century or more is arguably the ultimate sustainable construction strategy one that not even the most ardent proponents of a net-zero-operations worldview claim could top. Historical buildings are more likely to house resilient, climate-responsive designs than are contemporary structures because traditionally, architects have far more often employed stout passive design elements (like thick masonry walls and high ceilings).[12] The resultant "performance gap" (if you could call it that) between the two kinds of structures means that reusing pre-1970 structures often make more sense from an environmental perspective than demolishing them and building something new, even if that new something is conceived by today's supposed top-talent architects.

The ecological benefits of adaptive reuse are evident.[13] One recent study, using a hedonic pricing model, demonstrated that the adaptive reuse of heritage tenement houses in Hong Kong led not only to significant economic uplift in the surrounding residential property values but also to a revitalized cultural vibrancy and a renaissance in neighbourhood identity. But the advantages of adaptive reuse extend far beyond ecological and economic aspects. They reach deeply into the realm of social sustainability.[14] A renewed focus on the potential of the types of places adaptive reuse can deliver is particularly important at a moment when the advent of artificial intelligence promises to eliminate many of the place-based jobs that people currently hold.[15] Upward of 80 percent of a building’s emissions occur during the operation of that building. Conversely, operational savings from energy-efficient buildings can be up to 50 percent of the energy consumption that would otherwise have occurred.

2. Global Case Studies of Adaptive Reuse

2.1 The Natural Capital Centre (Ecotrust Building), Portland

The Natural Capital Centre also known as the Ecotrust Building stands as a hallmark of sustainable adaptive reuse in Portland. Originally constructed in 1895 as the McCraken Company Warehouse and later serving as the Central Truck Terminal, this Romanesque brick structure retained its architectural heritage during a 1999-2001 transformation. Ecotrust acquired the building in 1998 and invested $12.4 million to renovate it as their headquarters and a hub for conservation-oriented commerce. In

2001, it achieved distinction as the first historic building in the United States to earn a LEED Gold certification, underscoring its pioneering role in green redevelopment. The retrofit process was both sustainable and strategic: two-thirds of the new wood installed was Forest Stewardship Council (FSC) certified, and impressively, 98% of demolition waste was reused, recycled, or reclaimed. The integration of a green roof and improved stormwater infrastructure further showcased how heritage preservation and environmental performance can coexist.[16] Today, the building houses a mix of nonprofit and for-profit tenants such as Patagonia and the City's Bureau of Planning and Sustainability making it both a cultural hub and a model for sustainable urban reuse.

Figure 1. Ecotrust Building (Natural Capital Centre), Portland

2.2 Industrial Heritage Reimagined in China

In Beijing's 798 Art Zone and Shanghai's M50 Creative Plaza, post-industrial factory complexes have been transformed into vibrant creative cultural districts. The 798 Art Zone, located in Beijing's Dashanzi area, contains decommissioned military factory buildings that are characterized by an architectural style influenced by the Bauhaus. These structures have been turned into galleries, studios, and exhibition spaces essentially, the cultural next door to the M50 in Shanghai. And Beijing, a city with a heavy identity imprint from the Ming and Qing Dynasties, is home to the 798 Art Zone, making it the second most visited cultural attraction after the Forbidden City next door.[17]

The criteria and success factors of adaptive reuse interventions were using a combination of methods. These methods included the use of questionnaires and engaging with case studies. Their assessment found three areas that were pivotal to the success of these districts. The first was government support.[18] The second was community participation. And the third was the preservation of what the researchers called industrial aesthetics. Now, while I can't be certain, since I can't see the future, I think these are three areas that we're going to have to focus on if we want adaptive reuse intervention to be successful here.[19]

Figure 2. 798 Art Zone, Beijing

2.3 De Ceuvel, Amsterdam

De Ceuvel is a prime example of regenerative adaptive reuse, located in a formerly polluted shipyard in the Buiksloterham neighbourhood of Amsterdam. It was started by an interdisciplinary team (2012) that secured a 10-year lease from the city to transform the site into a lab of living circular design.

- Team members used phytoremediation, a method employing specific plants to absorb contaminants, to clean the soil now growing lemon balm, marshmallow, and other plants.
- Founding member Marco Wiegand introduced bio-digesters to turn putrid organic waste into biogas.
- They salvaged houseboats and turned them into something far from a clichéd workspace.
- The site also has a café, event spaces, and classrooms serving the next item on De Ceuvel's agenda: educational outreach.

De Ceuvel neatly combines green technology with social enterprise and ecological care. It has all the necessary components for an almost completely autonomous, off-grid, and water-independent building. It features composting toilets, solar energy systems, heat exchangers, rainwater harvesting, and circular water treatment. These systems collectively contribute to approximately 75% less water consumption than conventional commercial spaces of similar size, while actively purifying the land. A community-driven governance model and interpretive paths invite public engagement and knowledge-sharing, underscoring the project’s experimental and educational ethos.

Figure 3. De Ceuvel, Amsterdam

3. Toward a Framework for Sustainable Adaptive Reuse

Adaptive reuse achieves its highest impact when guided by a robust, multidimensional framework that goes beyond technical feasibility to incorporate cultural, social, and environmental values.[20] Such an evaluation model specifically for industrial heritage: their multicriteria evaluation framework treats intrinsic socio-cultural values such as authenticity, collective memory, and community identity as central to decision-making, alongside economic viability and environmental performance; this inclusive, participatory process helps stakeholders converge on the most appropriate transformation scenario. The design principles to ensure that adaptive reuse transcends superficial preservation. Their guidelines advocate maximal retention of existing fabric, restoration of passive systems (e.g., natural ventilation, daylighting), preservation of microclimates tied to original site plantings, and minimal site disturbance. These low-impact strategies are especially relevant for heritage structures, allowing them to retain environmental function and cultural resonance over time.[21] Equally important is resisting the commodification of heritage. Though industrial heritage can catalyse urban renewal, over-commercialization risks eroding labour histories and community narratives. To counteract this, adaptive reuse needs interpretive depth and programming that respects cultural narratives seeing heritage not as decor but as a living legacy integral to identity.

Contemporary scholarship, especially in the cultural heritage sector, emphasizes the need to link adaptive reuse with circular economy logics and human-centric values. The CLIC project (Circular Models for the Recovery and Reuse of Cultural Heritage) offers a structured, circular evaluation

framework that serves both ex-ante and ex-post decision making for heritage reuse).[22] The project considers three dimensions of the framework: regenerative capacity (how well a project restores the ecological context), symbiotic capacity (how well a project relates to the immediate physical and urban context), and generative capacity (how well a project creates new cultural and economic forms).[23] Fairly innovative, this project uses a blend of quite traditional indicators, quantitative ones as well as qualitative indicators derived from stakeholder assessments that serve as diagnostics in the different dimensions. The framework has an ethical core. It poses not only the question of how assets look after use but also (and importantly) to whom they relate and for what sorts of purposes cultural or otherwise.[24]

4. Discussion: Adaptive Reuse as Regenerative Urban Practice

Taken together, theory and exemplary case studies reveal that adaptive reuse transcends mere architectural recycling it embodies regenerative urbanism. Instead of perpetuating linear development cycles of demolition and new construction, adaptive reuse nurtures circularity, collective memory, and urban resilience. Existing structures become anchors for both ecological and narrative continuity, providing layers that connect past, present, and future urban life. In regenerative design thinking, buildings become living systems: their materially continuous form preserves embodied resource flows, while passive systems (daylighting, natural ventilation, thick thermal mass) enhance environmental resilience, and programming anchored in place fosters social cohesion. This framing aligns with a broader shift in urban design toward "regeneration", where architecture no longer just avoids damage, but actively restores ecological systems and community well-being. Building on this, adaptive reuse can play a catalytic role in advancing post-2030 urban sustainability, offering a pathway toward inclusive and place-based regeneration.[25]

Repurposing industrial heritage must move beyond conventional sustainability metrics like GDP or LEED scores; instead, it should prioritize well-being, circular-economy principles, and decolonial placemaking that amplifies community agency and resists displacement or gentrification. These reframing positions adaptive reuse not only as a green solution, but also as a mechanism for social justice and ecological renewal. Yet the transformative potential of adaptive reuse must reckon with the persistent barriers of cumulative cultural, regulatory, and economic challenges.[26] The scholars identify these challenges and articulate their nature: concerns over loss of authenticity and devaluation of heritage; restrictive heritage zoning; outdated building codes; hazardous materials abatement; and limited financing opportunities in smaller municipalities. On the industry side, many developers and project-level voices raise concerns over regulatory complexity, unexpected remediation costs (e.g., for asbestos), and ownership fragmentation.

5. Conclusion

Adaptive reuse stands as a vital, integrated strategy for forging sustainable and inclusive urban futures. Through ecological conservation, cultural continuity, and economic activation, it enriches urban landscapes far beyond mere retrofit. Iconic projects from Portland’s LEED-certified Ecotrust building, to China’s vibrant creative districts, to De Ceuvel’s ecologically regenerative campus demonstrate how cities can heal, reminisce, and innovate simultaneously. Crucially, adaptive reuse can deliver measurable contributions to Sustainable Development Goals: research shows it strongly advances SDG 11 (sustainable cities), SDG 17 (partnerships), and SDG 4 (inclusive education), through inclusive decision-making, architectural preservation, and public-private collaborations. Embedding adaptive reuse at the heart of urban policy and design with inclusive frameworks, ecological-first principles, and participatory governance ensures that cities evolve without erasing

their foundational layers. Moreover, adaptive reuse offers profound opportunities for economic and social regeneration, especially in disused or marginalized urban quarters. Land recycling strategies repurpose abandoned industrial sites into mixed-use assets like community retail, affordable housing, or green spaces catalysing private investment, expanding job markets, and enriching the public realm. These transformations are especially vital amid growing inequities, positioning adaptive reuse as both pragmatic and equitable pathway forward. However, realizing adaptive reuse's full potential demands systemic support: streamlined regulatory environments that accommodate performance-based retrofits; financial instruments like grants and tax credits that value cultural and social dividend; technical innovation to address hazards and structural complexities; and ambition to advance culturally grounded, decolonial placemaking that protects communities from displacement and commodification. Only through such integrated, values-driven models can adaptive reuse meaningfully contribute to resilient, regenerative, and inclusive urban futures. In closing, adaptive reuse integrates memory with movement, preserving urban muscle while welcoming new life. It transcends being a stopgap, it is a foundational strategy for cities navigating climate urgency and heritage loss. As urban futures unfold, adaptive reuse offers a grounded, hopeful path: one where past and future coexist in resilient, inclusive, and life-affirming harmony.

NOTES

[1] Casey ZS. Mehan, A. (2023). Oil Heritage in the Golden Triangle. Spindletop-Gladys City Boomtown. TICCIH Bulletin No. 101; pp. 38–40.

[2] Mehan, A. (2024). Reimagining Industrial Legacy: Strategic Urban Adaptation for Climate Resilience in an Era of Radical Environmental Change. In: Calabrò, F., Madureira, L., Morabito, F.C., Piñeira Mantiñán, M.J. (eds) Networks, Markets & People. NMP 2024. Lecture Notes in Networks and Systems, vol 1188. Springer, Cham. https://doi.org/10.1007/978-3-031-74716-8_32

[3] International Energy Agency. (2022). Buildings – Energy System.

[4] United Nations Environment Programme. (2024, March 7). Not yet built for purpose: Building sector emissions still high. UNEP News.

[5] Mehan, A. (2023). Visualizing Change in Radical Cities and Power of Imagery in Urban Transformation. img journal, (8), 182-201. https://doi.org/10.6092/issn.2724-2463/16093

[6] American Institute of Architects. (2024). Building Reuse: A Proven Climate and Economic Strategy.

[7] ZGF Architects. (2022). Continuing Education: Embodied Carbon & Adaptive Reuse.

[8] New Studio Architecture. (2023). Adaptive Reuse: A Strategy for Holding History and Carbon.

[9] Mehan, A. (Ed.). (2025). After Oil: A Comparative Analysis of Oil Heritage, Urban Transformations, and Resilience Paradigms. Springer Nature.

[10] Varış Husar, S. C., Mehan, A., Husar, M., Ceylan-Çalışkan, R., Erkan-Öcek, R., Song, S., & Leemans, S. (2025). Permeability of Borders, Ideas and Spaces: Reimagining Europe's Spatial Futures from the Perspective of New Generation of Planners. disP - The Planning Review, 61(1), 24–40. https://doi.org/10.1080/02513625.2025.2518856

[11] Mehan, A., & Casey, Z. S. (2023). Blue Infrastructures: An Exploration of Oceanic Networks and Urban–Industrial–Energy Interactions in the Gulf of Mexico. Sustainability, 15(18), 13699. https://doi.org/10.3390/su151813699

[12] Mehan, A., Casey, Z.S. (2024). The Petrological Imprint: A Comprehensive Study of Spindletop's Role in the Morphogenesis of the Golden Triangle of Texas. In: Calabrò, F., Madureira, L., Morabito, F.C., Piñeira Mantiñán, M.J. (eds) Networks, Markets & People. NMP 2024. Lecture Notes in Networks and Systems, vol 1183. Springer, Cham. https://doi.org/10.1007/978-3-031-74501-0_1

[13] Mehan, A. (2025). Adaptive reuse as a catalyst for post-2030 urban sustainability: rethinking industrial heritage beyond the SDGs. Discov Sustain 6, 598. https://doi.org/10.1007/s43621-025-01462-9

[14] Mehan, A., & Stuckemeyer, J. (2023). Urbanismo en la era de las transiciones radicales: hacia paisajes urbanos postindustriales. In Transición energética y construcción social del territorio ante el reto del cambio climático y el nuevo marcogeopolítico (pp. 145-174). Aranzadi.

[15] Mehan, A. (2025). Reimagining post-industrial landscapes through the lens of sustainable development. AGATHÓN| International Journal of Architecture, Art and Design, 17, 120 129. https://doi.org/10.69143/2464-9309/1772025

[16] Mehan, A. (2025). Introduction: Navigating a Post-Oil Future. In: Mehan, A. (eds) After Oil: A Comparative Analysis of Oil Heritage, Urban Transformations, and Resilience Paradigms. Springer, Cham. https://doi.org/10.1007/978-3-031-92188-9_1

[17] Mehan, A., Mostafavi, S. (2024). Immersive Art and Urban Heritage: An Interdisciplinary Study of Socio-Environmental Justice in Houston and Amsterdam. In: Moral-Andrés, F., Merino-Gómez, E., Reviriego, P. (eds) Decoding Cultural Heritage. Springer, Cham. https://doi.org/10.1007/978-3-031-57675-1_19

[18] Varış Husar, S. C., Mehan, A., Erkan, R., Gall, T., Allkja, L., Husar, M., & Hendawy, M. (2023). What's next? Some priorities for young planning scholars to tackle tomorrow's complex challenges. European Planning Studies, 31(11), 2368–2384. https://doi.org/10.1080/09654313.2023.2218417

[19] Mehan, A., & Razak, R. A. (2022). LA FUTURA EREDITÀ ENERGETICA NEL GOLFO PERSICO E NEL MAR CINESE MERIDIONALE: IL CASO DEL PATRIMONIO PETROLIFERO IN IRAN E MALESIA. LaborEst, (24), 57-63. DOI: 10.19254/LaborEst.24.09

[20] Abastante, F., Corrente, S., Greco, S., Lami, I. M., & Mecca, B. (2020). The introduction of the SRF-II method to compare hypotheses of adaptive reuse for an iconic historical building. Operational Research. Advance online publication. https://doi.org/10.1007/s12351-020-00611-4

[21] Kee, T. Y. C. (2018). Sustainable adaptive reuse – Economic impact of cultural heritage. Journal of Cultural Heritage Management and Sustainable Development, 9(2). https://doi.org/10.1108/JCHMSD-06-2018-0044

[22] Szopińska-Mularz, M., Prokop, A., Wikiera, M., Bukowy, W., Forsman, F., & Vikström, S. (2025). Adaptive reuse of urban structures as a driver of Sustainable Development Goals: A systematic literature review. Sustainability, 17(11), Article 4963. https://doi.org/10.3390/su17114963

[23] Hu, M. (2024). Assessing the environmental benefits of adaptive reuse in building renovation: A life cycle assessment approach. Journal of Cultural Heritage Management and Sustainable Development. https://doi.org/10.1080/27658511.2024.2375439

[24] Szopińska-Mularz, M., Prokop, A., Wikiera, M., Bukowy, W., Forsman, F., & Vikström, S. (2025). Adaptive reuse of urban structures as a driver of Sustainable Development Goals: A systematic literature review. Sustainability, 17(11), Article 4963. https://doi.org/10.3390/su17114963

[25] Nocca, F., Bosone, M., & Orabona, M. (2024). Multicriteria evaluation framework for industrial heritage adaptive reuse: The role of the 'intrinsic value'. Land, 13(8), 1266. https://doi.org/10.3390/land13081266

[26] Gürsel, A. P., et al. (2023). What are the energy and greenhouse gas benefits of building reuse? Energy & Buildings. https://doi.org/10.1016/j.enbuild.2023.112530

BIBLOGRAPHY

Abastante, F., Corrente, S., Greco, S., Lami, I. M., & Mecca, B. (2020). *The introduction of the SRF II method to compare hypotheses of adaptive reuse for an iconic historical building.* Operational Research. Advance online publication. https://doi.org/10.1007/s12351-020-00611-4

American Institute of Architects. (2024). *Building Reuse: A Proven Climate and Economic Strategy.*

Casey ZS. & Mehan, A. (2023). *Oil Heritage in the Golden Triangle. Spindletop-Gladys City Boomtown.* TICCIH Bulletin No. 101; pp. 38–40.

Gürsel, A. P., et al. (2023). *What are the energy and greenhouse gas benefits of building reuse?* Energy & Buildings. https://doi.org/10.1016/j.enbuild.2023.112530

Hu, M. (2024). *Assessing the environmental benefits of adaptive reuse in building renovation: A life cycle assessment approach.* Journal of Cultural Heritage Management and Sustainable Development. https://doi.org/10.1080/27658511.2024.2375439

International Energy Agency. (2022). *Buildings – Energy System.*

Kee, T. Y. C. (2018). *Sustainable adaptive reuse – Economic impact of cultural heritage.* Journal of Cultural Heritage Management and Sustainable Development, 9(2). https://doi.org/10.1108/JCHMSD-06-2018-0044

Mehan, A. (2023). *Visualizing Change in Radical Cities and Power of Imagery in Urban Transformation.* img journal, (8), 182-201. https://doi.org/10.6092/issn.2724-2463/16093
Mehan, A. (2024). *Reimagining Industrial Legacy: Strategic Urban Adaptation for Climate Resilience in an Era of Radical Environmental Change.* In: Calabrò, F., Madureira, L., Morabito, F.C., Piñeira Mantiñán, M.J. (eds) Networks, Markets & People. NMP 2024. Lecture Notes in Networks and Systems, vol 1188. Springer, Cham. https://doi.org/10.1007/978-3-031-74716-8_32

Mehan, A. (2025). *Adaptive reuse as a catalyst for post-2030 urban sustainability: rethinking industrial heritage beyond the SDGs.* Discov Sustain 6, 598. https://doi.org/10.1007/s43621-025-01462-9

Mehan, A. (2025). *Introduction: Navigating a Post-Oil Future.* In: Mehan, A. (eds) After Oil: A Comparative Analysis of Oil Heritage, Urban Transformations, and Resilience Paradigms. Springer, Cham. https://doi.org/10.1007/978-3-031-92188-9_1

Mehan, A. & Casey, Z. S. (2023). *Blue Infrastructures: An Exploration of Oceanic Networks and Urban–Industrial–Energy Interactions in the Gulf of Mexico.* Sustainability, 15(18), 13699. https://doi.org/10.3390/su151813699

Mehan, A. & Razak, R. A. (2022). *LA FUTURA EREDITÀ ENERGETICA NEL GOLFO PERSICO E NEL MAR CINESE MERIDIONALE: IL CASO DEL PATRIMONIO PETROLIFERO IN IRAN E MALESIA.* LaborEst, (24), 57-63. DOI: 10.19254/LaborEst.24.09

Mehan, A. & Stuckemeyer, J. (2023). *Urbanismo en la era de las transiciones radicales: hacia paisajes urbanos postindustriales.* In *Transición energética y construcción social del territorio ante el reto del cambio climático y el nuevo marcogeopolítico* (pp. 145-174). Aranzadi.

Mehan, A. & Mostafavi, S. (2024). *Immersive Art and Urban Heritage: An Interdisciplinary Study of Socio-Environmental Justice in Houston and Amsterdam.* In: Moral-Andrés, F., Merino-Gómez, E., Reviriego, P. (eds) *Decoding Cultural Heritage.* Springer, Cham. https://doi.org/10.1007/978-3-031-57675-1_19

Mehan, A. (Ed.). (2025). *After Oil: A Comparative Analysis of Oil Heritage, Urban Transformations, and Resilience Paradigms.* Springer Nature.

New Studio Architecture. (2023). *Adaptive Reuse: A Strategy for Holding History and Carbon.*

Nocca, F., Bosone, M., & Orabona, M. (2024). *Multicriteria evaluation framework for industrial heritage adaptive reuse: The role of the 'intrinsic value'.* Land, 13(8), 1266. https://doi.org/10.3390/land13081266

Szopińska-Mularz, M., Prokop, A., Wikiera, M., Bukowy, W., Forsman, F., & Vikström, S. (2025). *Adaptive reuse of urban structures as a driver of Sustainable Development Goals: A systematic literature review.* Sustainability, 17(11), Article 4963. https://doi.org/10.3390/su17114963

United Nations Environment Programme. (2024, March 7). *Not yet built for purpose: Building sector emissions still high.* UNEP News.

Varış Husar, S. C., Mehan, A., Erkan-Öcek, R., Gall, T., Allkja, L., Husar, M., & Hendawy, M. (2023). *What's next? Some priorities for young planning scholars to tackle tomorrow's complex challenges.* European Planning Studies, 31(11), 2368–2384. https://doi.org/10.1080/09654313.2023.2218417

Varış Husar, S. C., Mehan, A., Husar, M., Ceylan-Çalışkan, R., Erkan-Öcek, R., Song, S., & Leemans, S. (2025). *Permeability of Borders, Ideas and Spaces: Reimagining Europe's Spatial Futures from the Perspective of New Generation of Planners.* disP - The Planning Review, 61(1), 24–40. https://doi.org/10.1080/02513625.2025.2518856

ZGF Architects. (2022). *Continuing Education: Embodied Carbon & Adaptive Reuse.*

FOSTERING URBAN SUSTAINABILITY AND RESILIENCE THROUGH THE DESIGN OF PUBLIC SPACES. THE CASE STUDY OF "XERSONISOS TIS PANAGIAS" IN KAVALA, GREECE

Author:
VARVARA TOURA, ALEXANDROS MPANTOGIAS

Affiliation:
EHESS/GEOGRAPHIE-CITES (FRANCE), SCHOOL OF ARCHITECTURE AUTH (GREECE)

INTRODUCTION

At the international level, public spaces play a pivotal role in shaping urban development. They serve as areas for social interaction, political expression, and cultural engagement.[1] In the context of 21st-century urban transformation, the design and management of public spaces increasingly incorporate the principles of sustainability, social, economic, and environmental. International frameworks such as the agenda 2030 and various social sustainability reports emphasize the centrality of public spaces in fostering inclusive social dynamics, promoting equity, and supporting environmentally and economically resilient urban systems.[2]

Despite their diverse forms and functions, public spaces possess the transformative potential to revitalize urban areas and serve as sites of hope (places where communities come together, reclaim agency, and imagine better futures) particularly in underdeveloped regions where access to recreational and communal environments is limited.[3] Given the global challenges associated with the strategic planning and design of public spaces, the paper focuses on their role within small and medium-sized cities, especially those grappling with socio-economic and environmental adversity. It seeks to explore the following question: In what ways can public spaces in small and medium-sized cities act as catalysts for inclusive and sustainable urban transformation, thereby contributing to the positive evolution of these communities?

The paper is based on a field work conducted in Kavala, a medium-sized city in Northern Greece between 2023 and 2025. Its main purpose is to question the appearance of planning methods and tools for the redevelopment of small and medium-sized urban areas like Kavala focusing on the design of public spaces while maintaining the characteristics of the urban fabric. What are the characteristics that define the identity of urban areas and need to be considered during the processes of design and planning of public spaces?

The Geography, Demography and Historical Legacy of Kavala

The city of Kavala is located in the north part of Greece, in the region of East Macedonia and Thrace, with an area of 351.35 square kilometres.[4] It is built near the Aegean Sea, close to the island of Thassos. Based on the 2021 population census, the Municipality of Kavala has 66,376 inhabitants.[5]

Figure 1. Kavala's Location in Northeastern Greece: A Coastal City on the Aegean Map, Source: Greece-map.net (Authorization for publication).

Mediterranean cities are affected during summer by heat waves while during the winter by snowstorms originating from Northern Europe. Kavala is characterized by its dense urban fabric and the absence of open green public spaces especially in the neighbourhoods that were built during the Ottoman era. We can distinguish the old city surrounded by the city's castle, built during the Ottoman Era and where it is located the "Xersonisos tis Panagia's" neighbourhood, from the expansions built during the 19th and 20th century which are located near the city's harbour.

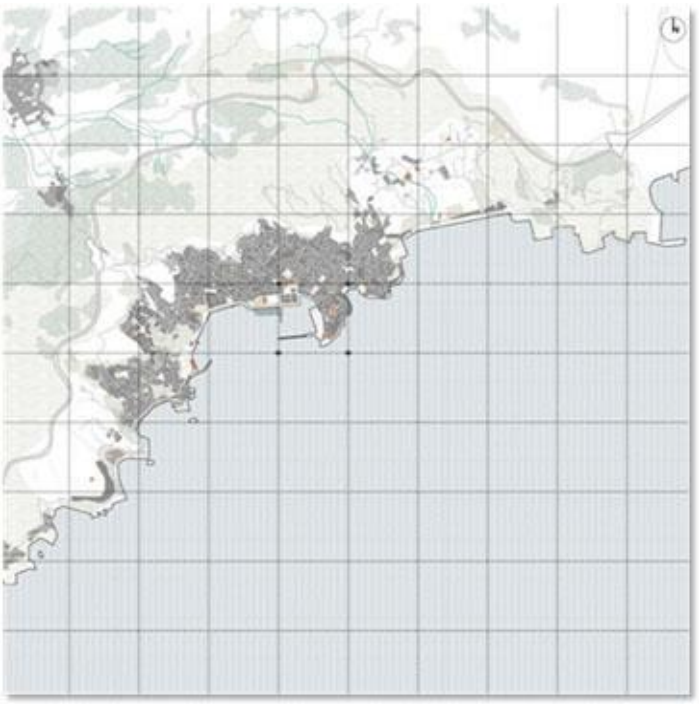


Figure 2. The compact and intricately layered urban structure of Kavala reflects its historical evolution and spatial constraints, Source: Varvara Toura and Alexandros Mpantogias (Authorization for publication).

After the Greek Turkish War of 1919–1922, the city of Kavala entered a new era of prosperity and development due to the industrial and agricultural activities.[6] Kavala became greatly involved and developed further in the processing and trading of tobacco mainly with European countries.[7] Many buildings related to the storage and processing of tobacco from that era are preserved in the city and act as landmarks of the city's past. As most of the Greek cities, especially small and medium-sized, Kavala faces in the 21st century the consequences of deindustrialisation and the closure of local enterprises, despite the fact that the presence of university departments in the area increases the local inhabitants' incomes due to apartments' rentals. Based on the social structure of the actual resident population Kavala is characterized as a city for the middle and working class (Table 1).

Socio-economic class	Estimated share of population	Description
Upper class/Affluent	~ 5-8%	Business owners, high-income professionals, real estate investors
Middle class	~ 35-40%	Public sector employees, educators, small business owners
Working class	~ 30-35%	Service workers, manual laborers, seasonal tourism/agriculture jobs
Retired/Pensioners	~ 20-22%	Seniors relying on state pensions, often central to family networks

Vulnerable groups	~ 5-10%	Unemployed youth, immigrants, disabled individuals, low-income families

Table 1. Estimated Socio-Economic Class Distribution in Kavala, a medium-sized city in Northeastern Greece
Source: Urbistat, Demographic data for Kavala, Greece

"Xersonisos tis Panagia's" neighbourhood maintains its physical and social characteristics since the era of Ottoman Empire. It is characterized by its narrow streets, the absence of open green public spaces and the organic and dense urban fabric which better corresponded to the needs of city's residents during the 18th and 19th century.

The Importance of Sustainability and Resilience conditions in dense urban areas

In contemporary urban design and planning, particularly within the frameworks of urban ecology[8] and environmental urbanism[9], public spaces are increasingly conceived as vital instruments for reintegrating nature into the urban fabric. These spaces often feature abundant vegetation, including trees and plants, and in some cases, involve the restoration of polluted natural elements such as urban streams, which are reintroduced into the city's landscape. Additionally, neglected areas, commonly referred to as urban voids[10] and often resulting from deindustrialization or the closure of local enterprises, are being repurposed as public spaces to reconnect them with the surrounding urban environment.

This reconversion of urban voids offers a "second life" to sites long marginalized due to socio-economic decline. Our central hypothesis is that transforming these voids into vibrant public spaces not only contributes to environmental sustainability and urban resilience but also serves as a mechanism for addressing social tensions. In underdeveloped neighbourhoods, such spaces become hubs for community interaction, recreation, and inclusive engagement.

A further dimension of contemporary public space design, related to Critical Heritage Studies[11] and the preservation of urban and cultural landscapes, involves the strategic placement of public spaces in areas rich in historical architecture and monuments. These interventions foster experiential connections with different eras of urban development and contribute to a deeper appreciation of the city's identity.

In light of this, we propose that the thoughtful planning of public spaces within historic districts, defined by their distinctive urban, cultural, and architectural character, can serve as a powerful tool for rebranding cities.[12] By promoting pedestrian and bicycle mobility, these spaces encourage exploration and reveal the hidden narratives embedded in the urban past.

THE COLLECTIVE APPROACH:
A MODEL FOR DESIGNING PUBLIC SPACES

Our approach integrates experimental urban design methodologies with participatory planning tools to reimagine public spaces as catalysts for urban resilience and sustainability. The project centres on the neighbourhood of "Xersonisos tis Panagia's" in Kavala, Northern Greece, and was developed within the framework of the *Public Spaces* urban design studio at the School of Architecture, Democritus University of Thrace.

Planning Methods and Tools

The design process employed a combination of:

- **Site analysis and spatial mapping** to identify underutilized urban voids and assess their potential for transformation.
- **Scenario planning** to envision alternative futures for the neighbourhood, focusing on adaptive reuse and ecological integration.
- **Morphological studies** to understand the spatial dynamics of dense urban environments and guide small-scale interventions.

These tools enabled a multi-scalar understanding of the urban fabric and informed a development scenario that prioritizes the reconversion of neglected spaces into inclusive public realms.

Field Research Methods

To ensure the design was grounded in local realities, we conducted:

- **Semi-structured interviews** with elected officials and long-term residents to gather insights of the historical context, governance challenges, and community aspirations.
- **Participatory workshops** where residents co-identified needs, proposed uses for public spaces, and evaluated preliminary design concepts.
- **On-site observations and behavioural mapping** to document patterns of movement, social interaction, and informal uses of space.
- **Photographic documentation, videos and sketching** to capture the character and atmosphere of the neighbourhood, informing the aesthetic and functional qualities of the proposals.
- **Documentation of the power dynamics of the city of Kavala and the region of East Macedonia and Thrace** in which administratively is part the city of Kavala.

This mixed-method approach allowed for a nuanced understanding of both spatial and social dimensions, ensuring that the proposed interventions were not only technically sound but also culturally and emotionally resonant.

Challenges and Main Problems: Greening Kavala's public spaces in historical neighbourhoods

Preserving Kavala's cultural heritage while enhancing its public spaces through ecological design presents a complex set of challenges. Key obstacles include securing sufficient funding from the Municipality of Kavala and the Region of East Macedonia and Thrace, fostering meaningful citizen

engagement in the planning and design processes, and identifying appropriate urban voids for redevelopment within the city's densely built environment. Despite these difficulties, several urban voids have been successfully identified in Kavala's historic district, the 'Xersonisos tis Panagia's' neighbourhood. These sites offer valuable opportunities to reconnect the city's residents with its rich architectural and urban legacy, while simultaneously contributing to a more sustainable and inclusive urban landscape.

Figure 3. Spatial discontinuities and underutilized zones within the 'Xersonisos tis Panagia's' historic neighbourhood, Source: Varvara Toura and Alexandros Mpantogias (Authorization for publication).

Observations from the field research in the 'Xersonisos tis Panagia's' neighbourhood:

- Green spaces: The city of Kavala, and particularly the historic neighbourhood of 'Xersonisos tis Panagia's', faces a notable scarcity of open green urban spaces relative to its densely built environment. The spatial organisation and land use patterns in this area were largely shaped by the influx of refugees from the Anatolia region following the 1923 population exchange. As a result, the neighbourhood experiences elevated temperatures during the summer months, exacerbated by the lack of natural shading and cooling elements. During interviews residents and visitors cited the discomfort felt when attempting to use the existing public spaces, which are largely devoid of trees, pergolas, or other climate-mitigating features that could enhance thermal comfort and usability.

Figure 4. Current distribution and characteristics of green spaces within the 'Xersonisos tis Panagia's' historic neighbourhood, Source: Varvara Toura and Alexandros Mpantogias (Authorization for publication).

- Mobility: Regarding mobility challenges in the 'Xersonisos tis Panagia's' neighbourhood, most urban voids are currently occupied as informal parking lots for residents and visitors. Simultaneously, the neighbourhood's main thoroughfare, Poulidou Street, lacks designated pedestrian pavements, which further complicate movement through the area. As a result, both inhabitants and visitors cited during interviews the significant difficulties they face when navigating the neighbourhood, whether on foot or by bicycle, due to the absence of pedestrian infrastructure and the dominance of vehicular use.

Figure 5. Current configuration and connectivity of the road network within the 'Xersonisos tis Panagia's' historic neighbourhood, Source: Varvara Toura and Alexandros Mpantogias (Authorization for publication).

- Sports and recreation facilities: In contemporary urban planning, sustainability and resilience are increasingly linked to recreational activities and sports, reflecting the emphasis on human health and well-being outlined in the United Nations' Agenda 2030.[13] However, the interviews with the residents of the 'Xersonisos tis Panagia's' neighbourhood revealed a significant gap: the absence of dedicated recreational and sports facilities that could support both social interaction and physical well-being. Residents, particularly teenagers and families with young children, cited a clear need for accessible spaces where they could engage in sports and leisure activities. The lack of such infrastructure not only limits opportunities for active living but also hinders the development of inclusive and socially vibrant public spaces in the neighbourhood.

- Local cultural heritage: The 'Xersonisos tis Panagia's' neighbourhood is one of the oldest districts in Kavala, distinguished by its 19th-century architecture and layered historical development spanning the Byzantine, Ottoman, and post-1923 refugee settlement periods. This rich historical tapestry is reflected in the presence of notable monuments such as the Imaret building and local landmarks like the lighthouse. However, a major challenge in appreciating the neighbourhood's urban landscape was revealed during the interviews with the residents, which is the limited visibility and accessibility of these heritage elements. Many monuments are situated in close proximity to modern constructions or are enclosed within private or restricted areas, making them difficult to recognize and engage with.

Figure 6. Current land use patterns within the 'Xersonisos tis Panagia's' historic neighbourhood (in orange colour are presented monuments and landmarks), Source: Varvara Toura and Alexandros Mpantogias (Authorization for publication).

The Way Forward: Actionable Steps towards Sustainability

To safeguard Kavala's heritage for future generations while steering its evolution toward a greener, more sustainable cityscape, we have co-developed a set of actionable measures with residents and municipal authorities. These measures form the backbone of a comprehensive, long-term strategy that brings all stakeholders into the sustainable redesign of Kavala's public spaces. At the same time, certain interventions, especially mobility-related improvements, required a more directive, top-down framework. This ensured alignment with the project's overall budget and the construction schedule established by the municipality. Below are the key recommendations derived from our research:

1. Increase of green spaces in dense urban areas

During consultations with local elected officials and residents, a shared interest emerged in enhancing the presence of trees and vegetation throughout the 'Xersonisos tis Panagias' neighbourhood. This perspective aligns with the principles outlined in the United Nations' Agenda 2030 and the urban design philosophy of Jan Gehl,[14] both of which emphasize the role of open green spaces in promoting public health and well-being through improved environmental conditions. In light of these findings, our development plan for the redesign of public spaces in the neighbourhood strongly advocates for the integration of more plants and trees. These elements are not only essential for climate adaptation and resilience, but also for enhancing the liveability of the area, especially during the increasingly intense summer heat. It is important to note that Kavala, situated in the Mediterranean region and adjacent to the sea, is particularly vulnerable to extreme summer temperatures. This geographic reality further underscores the urgency of implementing green infrastructure as a core component of sustainable urban planning.

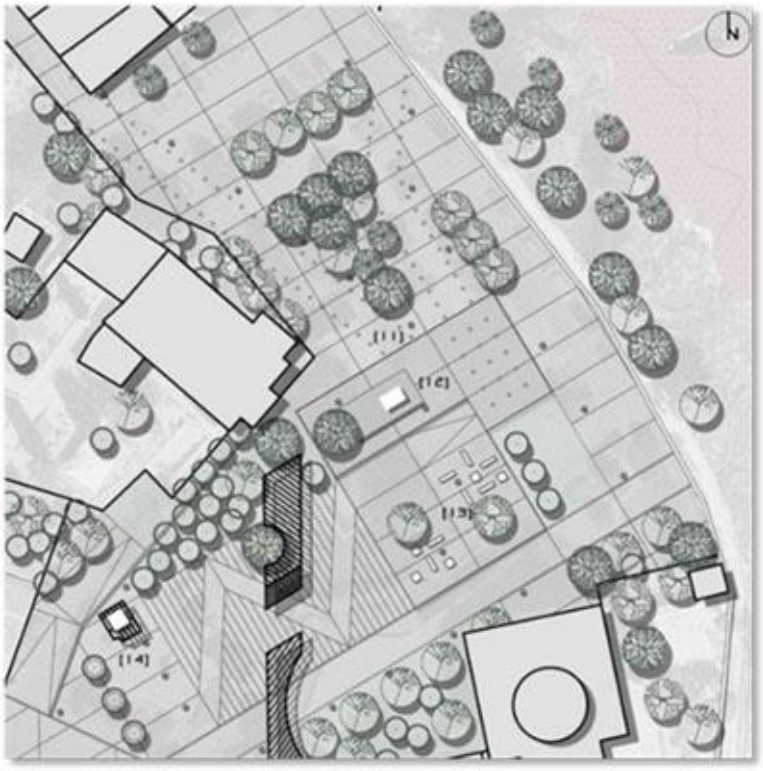


Figure 7. Strategic proposal for the ecological enhancement of existing public spaces within the 'Xersonisos tis Panagia's' historic neighbourhood, Source: Varvara Toura and Alexandros Mpantogias (Authorization for publication).

2. Promoting sustainable mobility

Our core strategy involves the redesign of several key streets in Kavala, particularly within the historic 'Xersonisos tis Panagia's' neighbourhood, based on the model of pedestrian-priority zones.[15] By transforming traffic-dominated corridors into green, community-oriented spaces, this model addresses critical urban challenges such as congestion, pollution, and road safety. The proposed redesign of Poulidou Street as a pedestrian-priority zone would significantly expand the public realm at street level, integrating vegetation, seating, and other urban amenities to foster both social interaction and environmental sustainability. This intervention aims to enhance the neighbourhood's liveability, promote inclusive mobility, and contribute to a healthier, more resilient urban landscape.

Figure 8. Strategic proposal for the transformation of street infrastructure in the 'Xersonisos tis Panagia's' neighbourhood into pedestrian-priority zones, Source: Varvara Toura and Alexandros Mpantogias (Authorization for publication).

3. Improving human health and well-being

In our development scenario, human health and well-being were identified as fundamental pillars of urban sustainability and resilience. In collaboration with local residents and municipal authorities, we proposed the transformation of existing enclosed open-air spaces, such as fenced schoolyards, into accessible public spaces. By repurposing these areas for recreational and sports activities, the initiative aims to foster greater social interaction and enhance the physical and mental well-being of both residents and visitors in the neighbourhood. This approach not only addresses the lack of inclusive public spaces[16] but also aligns with broader goals of creating healthier, more connected urban communities.

Figure 9. Design proposal for the adaptive reuse of schoolyards in the 'Xersonisos tis Panagia's' neighbourhood as multifunctional open-air public spaces for recreation and sport, Source: Varvara Toura and Alexandros Mpantogias (Authorization for publication).

4. Protection and promotion of the local cultural heritage

As part of our strategy for the revalorization of Kavala's historical spaces, we approached sustainability and resilience as concepts deeply intertwined with an urban landscape that reflects and repurposes all phases of the city's history in response to contemporary needs. By designing open public spaces adjacent to key landmarks and monuments and incorporating appropriate vegetation, such as tall trees and urban amenities like pergolas and benches, we aim to enhance the visibility and appreciation of these heritage elements. The integration of natural and cultural features within the public realm fosters a sense of continuity[17] between past and present, while contributing to the environmental and social sustainability of Kavala's urban fabric.

Figure 10. Design proposal for enhancing open public spaces adjacent to cultural landmarks within the 'Xersonisos tis Panagia's' historic neighbourhood, Source: Varvara Toura and Alexandros Mpantogias (Authorization for publication).

CONCLUSION: BUILDING A SUSTAINABLE FUTURE FOR URBAN AREAS IN THE MEDITERRENEAN REGION

The study of a real-world urban context marked by socio-economic challenges and a scarcity of public spaces highlights the urgent need to reframe public space planning in disadvantaged small and medium-sized cities as a transformative tool. Such spaces can serve as catalysts for a more liveable urban future by integrating principles of both social and environmental sustainability. Public spaces become truly impactful when their design is the result of collaborative efforts among local elected officials, residents, researchers, and practitioners. This inclusive process should go beyond mere consultation to embrace co-design and co-production, ensuring that solutions are not only technically sound but also deeply responsive to the lived realities and aspirations of the community.

In the case study of Kavala, and specifically the 'Xersonisos tis Panagia's' neighbourhood, the unique characteristics of the urban landscape are clearly reflected in the design of public spaces. Historical buildings, monuments, and landmarks, many dating back to different periods of the city's evolution, are not only symbolic remnants of the past but also active components of contemporary urban life, often restored and repurposed. When these spaces are open and welcoming, they offer residents, researchers, and visitors a richer experience of urban discovery, one that connects the city's historical layers with its present-day identity. To preserve this delicate balance, planning policies should include the designation of protection zones around culturally significant districts. These zones can safeguard against the pressures of mass tourism[18] and large-scale development projects that risk undermining the historical and cultural integrity of the area.

NOTES

[1] Ivan Siláči and Ľubica Vitková, “Public Spaces as the Reflection of Society and Its Culture,” *IOP Conference Series: Materials Science and Engineering* 245, no. 4 (2017): 042009, https://doi.org/10.1088/1757-899X/245/4/042009.

[2] United Nations, *Transforming Our World: The 2030 Agenda for Sustainable Development* (New York: United Nations, 2015), accessed May 10, 2025, https://sdgs.un.org/sites/default/files/publications/21252030% 20Agenda%20for%20Sustainable%20Development%20web.pdf.

[3] Nardine El-Bardisy, “Urban Culture as a Challenge of Enhancing Social Interaction in Public Spaces,” *Discover Cities* 1, no. 27 (2024), https://doi.org/10.1007/s44327-024-00030-6.

[4] Hellenic Statistical Authority, *Population & Housing Census 2001 (Including Area and Average Elevation)* (Athens: Hellenic Statistical Authority, 2001), accessed May 10, 2025, https://dlib.statistics.gr/Book/ GRESYE_02_0101_00098%20.pdf.

[5] Hellenic Statistical Authority, *Greek Population Census*, n.d., accessed May 10, 2025, https://www.statistics.gr/documents/20181/17286366/APOF_APOT_MON_DHM_KOIN.pdf/41ae8e6c-5860-b58e-84f7-b64f9bc53ec4.

[6] Nikos Karagiannakidis and Kyriakos Likourinos, *Neapolis–Christoupolis–Kavala* (Kavala: Municipality of Kavala, 2009).

[7] Lila Theodoridou and Athena Moustaka, “Tobacco Firms and Their Purchasing Offices in Cavalla during the First Half of the 20th Century: The Dissemination of the Austro-Hungarian and Swedish Architectural Style,” in *Tobacco Roads: Vienna to Kavala: Technology Transfer in the Early Twentieth Century*, ed. Municipality of Kavala (Kavala: Municipality of Kavala, 2013), 5–7, accessed May 10, 2025, https://www.researchgate.net/publication/268519980_Tobacco_Roads_Vienna_to_Kavala_Technology_Transfer_in_the_Early_Twentieth_Century.

[8] Pramit Verma et al., *Urban Ecology: Emerging Patterns and Social-Ecological Systems* (Amsterdam: Elsevier, 2020).

[9] Frederick R. Steiner, *Nature and Cities: The Ecological Imperative in Urban Design and Planning* (Cambridge, MA: Lincoln Institute of Land Policy, 2016).

[10] Sergio Lopez-Pineiro, *A Glossary of Urban Voids* (Berlin: De Gruyter, 2020).

[11] Tuuli Lähdesmäki, Suzie Thomas, and Yujie Zhu, *Politics of Scale: New Directions in Critical Heritage Studies* (New York: Berghahn Books, 2023).

[12] Mihalis Kavaratzis, Gary Warnaby, and Gregory J. Ashworth, *Rethinking Place Branding: Comprehensive Brand Development for Cities and Regions* (Berlin: Springer, 2015).

[13] United Nations, *Transforming Our World: The 2030 Agenda for Sustainable Development* (New York: United Nations, 2015), accessed May 10, 2025.

[14] Jan Gehl, *Life Between Buildings: Using Public Space* (Copenhagen: Danish Architectural Press, 2006).

[15] Chris van Uffelen, *Pedestrian Zones: Car-Free Urban Spaces* (Luzern: Braun Publishing, 2015).

[16] Ali Madanipour, *Rethinking Public Space* (Cheltenham, UK: Edward Elgar Publishing, 2023).

[17] Alison Gilchrist, *The Well-Connected Community: A Networking Approach to Community Development* (Bristol: Policy Press, 2004).

[18] Harald Pechlaner, Elisa Innerhofer, and Greta Erschbamer, *Overtourism: Tourism Management and Solutions* (Abingdon, UK: Routledge, 2019).

BIBLIOGRAPHY

Bélanger, Hélène. “Public Spaces in Gentrifying Neighborhoods: Conflicting Meanings?” *ResearchGate*. Accessed May 3, 2025. https://www.researchgate.net/publication/228891732_Public_Spaces_in_Gentrifying_Neighbourhoods_Conflicting_Meanings.

Church, Chris, Adam Cade, and Adrienne Grant. *An Environment for Everyone: Social Exclusion, Poverty and Environmental Action*. London: CDF Publications, 1998.

El-Bardisy, Nardine. “Urban Culture as a Challenge of Enhancing Social Interaction in Public Spaces.” *Discover Cities* 1, no. 27 (2024). https://doi.org/10.1007/s44327-024-00030-6.

El-Kholei, Ahmed O., and Ghada Yassein. “Professionals’ Perceptions for Designing Vibrant Public Spaces: Theory and Praxis.” *Ain Shams Engineering Journal* 13 (2022). Accessed May 3, 2025. https://www.sciencedirect.com/science/article/pii/S2090447922000387#bi005.

Gehl, Jan. *Life Between Buildings: Using Public Space*. Copenhagen: Danish Architectural Press, 2006.

Gehl, Jan. *Cities for People*. Washington, DC: Island Press, 2010.

Gilchrist, Alison. *The Well-Connected Community: A Networking Approach to Community Development*. Bristol: Policy Press, 2004. Gutiérrez, Fernando H. “Gentrification, Homogenization and Sanitization of Public Space? Evidence from the Historic Centre of Mexico City.” *Academia.edu*. Accessed May 3, 2025. https://www.academia.edu/122068774/Gentrification_Homogenisation_and_Sanitisation_of_Public_Space_Evidence_from_the_Historic_Centre_of_Mexico_City.

Harrison, Rodney, Nélia Dias, and Kristian Kristiansen. *Critical Heritage Studies and the Futures of Europe*. London: UCL Press, 2023.

Harvey, David. “The Right to the City.” *New Left Review* 53 (2008). Accessed May 3, 2025. https://newleftreview.org/issues/ii53/articles/david-harvey-the-right-to-the-city.

Hellenic Statistical Authority. *Greek Population Census*. Athens: Hellenic Statistical Authority, n.d. Accessed May 10, 2025. https://www.statistics.gr/documents/20181/17286366/APOF_APOT_MON_DHM_ KOIN.pdf/41ae8e6c-5860-b58e-84f7-b64f9bc53ec4.

Hellenic Statistical Authority. *Population & Housing Census 2001 (Including Area and Average Elevation)*. Athens: Hellenic Statistical Authority, 2001. Accessed May 10, 2025. https://dlib.statistics.gr/Book/GRESYE_02_0101_00098%20.pdf.

Karagiannakidis, Nikos, and Kyriakos Likourinos. *Neapolis–Christoupolis–Kavala*. Kavala: Municipality of Kavala, 2009.

Kavaratzis, Mihalis, Gary Warnaby, and Gregory J. Ashworth. *Rethinking Place Branding: Comprehensive Brand Development for Cities and Regions*. Berlin: Springer, 2015.

Lähdesmäki, Tuuli, Suzie Thomas, and Yujie Zhu. *Politics of Scale: New Directions in Critical Heritage Studies*. New York: Berghahn Books, 2023.

Lopez-Pineiro, Sergio. *A Glossary of Urban Voids*. Berlin: De Gruyter, 2020.

Madanipour, Ali. *Rethinking Public Space*. Cheltenham, UK: Edward Elgar Publishing, 2023.

Pechlaner, Harald, Elisa Innerhofer, and Greta Erschbamer. *Overtourism: Tourism Management and Solutions*. Abingdon, UK: Routledge, 2019.

Roseland, Mark. *Towards Sustainable Communities: A Resource Book for Municipal and Local Governments*. Ottawa: National Round Table on the Environment and the Economy, 1992.

Sanoff, Henry. *Community Participation Methods in Design and Planning*. New York: John Wiley & Sons, 2000.

Schmid, Hillel. *Neighborhood Self-Management: Experiments in Civil Society*. New York: Kluwer Academic/Plenum Publishers, 2001.

Siláči, Ivan, and Ľubica Vitková. “Public Spaces as the Reflection of Society and Its Culture.” *IOP Conference Series: Materials Science and Engineering* 245, no. 4 (2017): 042009. https://doi.org/10.1088/1757-899X/245/4/042009.

Steiner, Frederick R. *Nature and Cities: The Ecological Imperative in Urban Design and Planning*. Cambridge, MA: Lincoln Institute of Land Policy, 2016.

Theodoridou, Lila, and Athena Moustaka. “Tobacco Firms and Their Purchasing Offices in Cavalla during the First Half of the 20th Century: The Dissemination of the Austro-Hungarian and Swedish Architectural Style.” In *Tobacco Roads: Vienna to Kavala: Technology Transfer in the Early Twentieth Century*, edited by Municipality of Kavala, 5-7. Kavala: Municipality of Kavala, 2013. Accessed May 10, 2025. https://www.researchgate.net/publication/268519980_Tobacco_Roads_Vienna_to_Kavala_Technology_Transfer_in_the_Early_Twentieth_Century.

United Nations. *Transforming Our World: The 2030 Agenda for Sustainable Development*. New York: United Nations, 2015. Accessed May 10, 2025. https://sdgs.un.org/sites/default/files/publications/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf.

Urban Initiative. *Handbook of Territorial & Local Development Strategies: Chapter 1 – Strategic Dimension*. Accessed May 3, 2025. https://portico.urban-initiative.eu/joint-research-center-jrc-territorial-development/handbook-territorial-and-local-development-strategies/handbook-territorial-local-development-strategies-chapter-1-strategic-dimension.

Van Uffelen, Chris. *Pedestrian Zones: Car-Free Urban Spaces*. Luzern: Braun Publishing, 2015.

Verma, Pramit, et al. *Urban Ecology: Emerging Patterns and Social-Ecological Systems*. Amsterdam: Elsevier, 2020.

Vukmirovic, Milena, Suzana Gavrilovic, and Dalibor Stojanovic. “The Improvement of the Comfort of Public Spaces as a Local Initiative in Coping with Climate Change.” *Sustainability* 11, no. 23 (2019). Accessed May 3, 2025. https://www.mdpi.com/2071-1050/11/23/6546.

THE FUTURE OF DWELLING: RE-STABLISHING A RELATIONSHIP WITH THE DESERT IN THE TIME OF CLIMATE CHANGE.

Author:
CAMILO CERRO

Affiliation:
AMERICAN UNIVERSITY OF SHARJAH

INTRODUCTION

In 50 years, the UAE went from a population of nomadic tribes, small ports, pearl divers, and fishing villages to a global financial and tourism hub. Before the skyscrapers, in the 18th and 19th centuries, the population of the Trucial States, the region's British protectorate, as the UAE was then known, lived very differently from the way they do today. Dwellings existed mainly in three forms: coral reefs, mud or stone brick construction, Barasti-style huts made of palm (Arish) walls supported by wooden frames, and tents made of sheep, camel, and goat wool and hair. A vernacular typology of walled family compounds planned around courtyards that followed local traditions of privacy, gender segregation, and social interaction. In 1958, with the discovery of oil reserves in Abu Dhabi, an era of rapid development began, displacing some traditional building typologies in favour of Western-influenced construction, which was alien to the local climate and culture of the region. A type of mid-century modernism that is now part of the local heritage became a blind spot in the evolution of regional architecture language.[1] This displacement experienced due to modernization is most evident at the residential level, where contemporary dwellings not designed for an arid tropical climate rely on air conditioning to survive temperatures that have reached 51.6 degrees Celsius and are expected to continue rising due to global warming.[2] The residential relationship to the desert has been lost. This article will examine local vernacular desert dwelling climate adaptability and modern sustainable technologies to propose building methods and socioeconomic inclusivity that could foster the development of a uniquely Emirati architectural language as part of the *Extreme Environment Studio* at the American University of Sharjah.

Residential Typological Displacement

The vernacular dwellings of the United Arab Emirates (UAE) showcase a rich heritage of desert adaptability, reflecting an understanding of geography, climate, and cultural sensitivities that emerged from the fusion of Bedouin and Islamic influences. A typological evolution that was overshadowed by the necessity to consolidate the population into cities for the creation of a modern state. Western housing typologies arrived in the region to accommodate the influx of Western workers required for

the development of the oil industry. The first Western-style houses were constructed in Saudi Arabia in 1938 by the California-Arabian Standard Oil Company (later known as ARAMCO). Two projects, the ARAMCO home ownership program and the Al-Malaz housing project, mark the beginning of a dramatic and widespread transformation of the vernacular building traditions in Saudi Arabia.[3] The first was divided into a Saudi and an American neighbourhood, representing the Gulf region's first example of Western-style urban planning, featuring an orthogonal street grid and detached villas with pitched roofs and picket fences. It presented a dystopian vision of American suburbia set in the middle of the Saudi desert. Due to ARAMCO's importance, the houses became a status symbol that spread throughout the Middle East. This development marked a significant transformation from traditional brick houses, Bedouin tents, and Arish houses, introducing Western architectural styles and urban planning principles to Saudi Arabia and subsequently to the broader Middle East. A phenomenon that took place particularly in areas related to oil exploration and development. These Western typologies became precursors to the suburban residential neighbourhoods of today, displacing vernacular typologies that were better adapted to the region, its climate, and culture. And more importantly, preventing the evolution of these vernacular typologies into their contemporary versions. At the Extreme Environment Studio of the American University of Sharjah, we are trying to reclaim the legacy of the vernacular, adapting it to the needs of regional communities as they adapt to climate change.

A Brief History of Housing in The UAE

The Post-Nomadic Period (up to 1763): Before the British colonial influence in the 18th century, Bedouin tribes inhabited the Gulf region, in a handful of settlements set up around oases. These communities made a living by raising livestock, fishing, and engaging in agriculture.[4] Their dwellings primarily took three forms: coral reefs, mud or stone brick construction, Barasti-style huts featuring palm (Arish) walls supported by wooden frames, and tents made from sheep, camel, and goat wool and hair. The tents were rectangular and supported in the centre by wooden poles made from date palm or Ghaf tree trunks, both of which were prevalent in the region. The wool used to make these tents was traditionally black or brown, and they were decorated with colourful tribal patterns. Inside, a privacy wall (Mehrem) separated the sexes. This type of dwelling was primarily used during the winter. In the summer, the Bedouin moved closer to the ocean and lived in Barasti-style hut dwellings, which allowed for cross ventilation, making the interior spaces cooler. A third dwelling typology emerged between the 19th and 20th centuries along the Coast, where pearl merchants constructed permanent dwellings from coral reef masonry, mud, or stone brick. The walls were deep, to serve as thermal insulators, with small openings to prevent sunlight from overheating the interiors. Larger mangrove poles imported from Africa served as structural roof beams, allowing for larger spans to be achieved. The ceilings supported by these beams were typically made from date palm planks and then sealed with a plaster finish. The size of these beams dictated the size of the house being built. Inland, a similar process was employed, utilizing stone or mud, depending on local availability. To cool down, both the brick buildings and the Barasti-style huts would utilize wind towers (Barajils), borrowed from Persia, to help direct wind into the dwellings. The centre of the brick houses featured a courtyard with all rooms opening into it, arranged in an introspective layout designed to foster privacy from the exterior while promoting openness within. A separate building with its own exterior entry would function as a meeting room (Majlis), where male family members would host their male guests, separated from the rest of the house. A vernacular typology of walled family compounds emerged, designed around courtyards that adhered to local traditions of privacy, gender segregation, and social interaction.

The Traditional Period (1763 to 1945): Between 1822 and 1971, the British Empire established an official colonial protectorate in the Gulf region to oversee its political and economic interests. This entity was named the *Persian Gulf Residency,* which came to be in response to the increasing trade activities with India.[5] The protectorate was headed by a Political Resident, who was the senior British official in the region, responsible for British relations with the participating states (which included what today are the UAE, Bahrain, Kuwait, Oman, Qatar, and parts of Iran). The region attracted migration from India and Persia, who were drawn in by the pearl trade, thereby increasing its commercial importance.[6] The ports and markets created distinct public centres where all social and ethnic groups interacted, beginning to shape urban areas. Cities like Dubai, Abu Dhabi, Sharjah, and Ras Al Khaimah emerged due to their connection to maritime trade and the British presence. These commercial enclaves were informal settlements where the lower classes lived in Barasti-style huts and tents while the higher classes resided in brick buildings.

The Modern Period (1945 to 1990): The Modern Period in the UAE witnessed significant changes, fueled by the discovery and exploitation of oil, which led to rapid modernization and the eventual establishment of the United Arab Emirates in 1971. The initial phase of urbanisation was characterized by a shift from traditional, often temporary, structures (Barasti-style huts) to more permanent masonry buildings, driven by rapid wealth growth that resulted in improved living conditions and the establishment of an infrastructural network, which included water supply, electricity, and sewage systems.[7] In 1966, the government launched a national housing program, often referred to as Shabiyaat (Neighbourhoods). It allocated public free housing to Bedouins in an effort to sedentarism the nomadic population, bringing them into urban areas. An idea designed to tie the Bedouin to the land, which was seen as an essential condition for the establishment of a modern state. At the centre of the program was the Sha'abi House (House of the People)[8], designed to be a modern interpretation of Bedouin dwelling habits. Formally, a compound setup by a series of concrete volumes, functionally distributed, enclosed by a wall, and devoid of any ornamentation. The concept of privacy played a crucial role in ensuring a clear division between female household members and the outside world. Separate entrances for family and guests were provided, and other changes were made in later iterations as the government assessed recommendations from the public. The success of these housing programs marked a significant advancement for the new state, showcasing the government and the rulers as protectors of the local community. The Sha'abi house serves as an example of the challenges presented by the loss of cultural identity due to the process of modernization, symbolizing a rejection of the past in pursuit of a new beginning. However, this type of dwelling would also become forgotten and lose its appeal as it no longer would serve as a status symbol among the local population when compared to contemporary housing.

The Contemporary Period (1990 to present): Despite the growth of the private sector in the Contemporary Period, the rulers of the UAE continue to be the primary drivers of development.[9] Their ability to make decisions regarding direct investments of oil and gas revenues into infrastructure and key projects contributes to their influence. Cities have expanded alongside the development of suburban residential areas, which include gated communities for expatriate professionals as well as distinct neighbourhoods for Emirati residents. The growth of the population and the residential construction that followed have led to urban sprawl, making for long commute times. Designed primarily for vehicle use, the substantial distances between workplaces and homes, combined with the high number of cars, have resulted in increased traffic and air pollution. Traffic congestion in the UAE costs about 10.5 billion AED (roughly $2.86 billion USD) annually in lost time, representing

3.5% of the country's GDP.[10] Making the energy used for transportation as high as that used for cooling buildings. In the UAE, cooling systems, primarily air conditioning, account for a significant portion of the nation's total energy consumption, with estimates ranging from 70% to 80%.[11] Urban density, smaller houses, and improved insulating materials could help mitigate these issues and some of the answers could come from the UAE's own residential precedents.

Looking in to how the past could inform the future

The displacement of a linear typological evolution has resulted in dwellings that are ill-prepared for desert living and rely on enclosures made from imported materials and air conditioning to function. This presents an unsustainable financial burden on the government. As we look into the future of dwelling in the region, multiple vernacular architectural concepts from the region's past can help guide the development of present and future typologies. The idea is not to be literal in reviving formal elements from the vernacular past, but instead to understand an ethos of better living that stems from understanding the site, local materials, and climate, thereby creating a more harmonious connection with the land. The proximity of building volumes, as in the Sha'abi house, can help create a denser urban landscape, reducing sprawl. Where buildings help shade each other. Mashrabiyas (screens) as seen in Barasti-style huts can be rethought as sun shields, minimizing the amount of sunlight a building receives while allowing for cross ventilation. Internal gardens could help lower temperatures while creating a biophilic relationship with plants, producing food, and aiding in preserving the region's biodiversity. Wall thickness and the use of local stone can also help improve the thermal insulation of buildings, reducing the need for air conditioning, saving energy, and lowering the dependency on imported building materials and equipment. After studying and visiting examples of all three vernacular building types presented above, the learners of the E*xtreme Environment Studio* spent a semester talking to experts and developing proposals for a dwelling that diverged from the current developer trend and explored how to use the past as a precedent in creating self-sufficient, sustainable, and culturally rooted residential designs.

The Extreme Environment Studio Methodology

The *Extreme Environment Studio* operates as the name suggests, in extreme environments, where sustainability, self-sufficiency, the use of local materials and methods, and the concept of a circular economy are essential elements in the type of projects the Studio undertakes. In this instance (Fall 2023), the 500-level studio focused on adapting ideas from the local vernacular residential typologies previously covered to foster the development of a uniquely Emirati architectural language that generates its uniqueness through an understanding of site and climate specificity. In doing so, the Studio concluded that in considering the future of living, a need for self-sufficiency was essential in the region. So, the Studio explored (infrastructural) grid independence in terms of energy production, water harvesting and storage, urban farming, carbon sequestration, support for local biodiversity, and waste management. This approach enabled learners to rethink their design process by combining their understanding of local vernacular dwelling design with current needs for sustainable residential development, allowing them to develop projects that would positively impact the local ecologies.

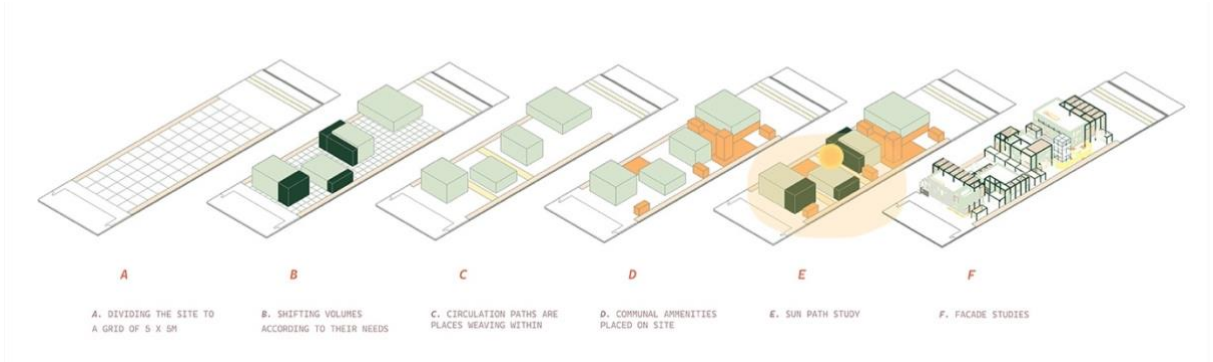
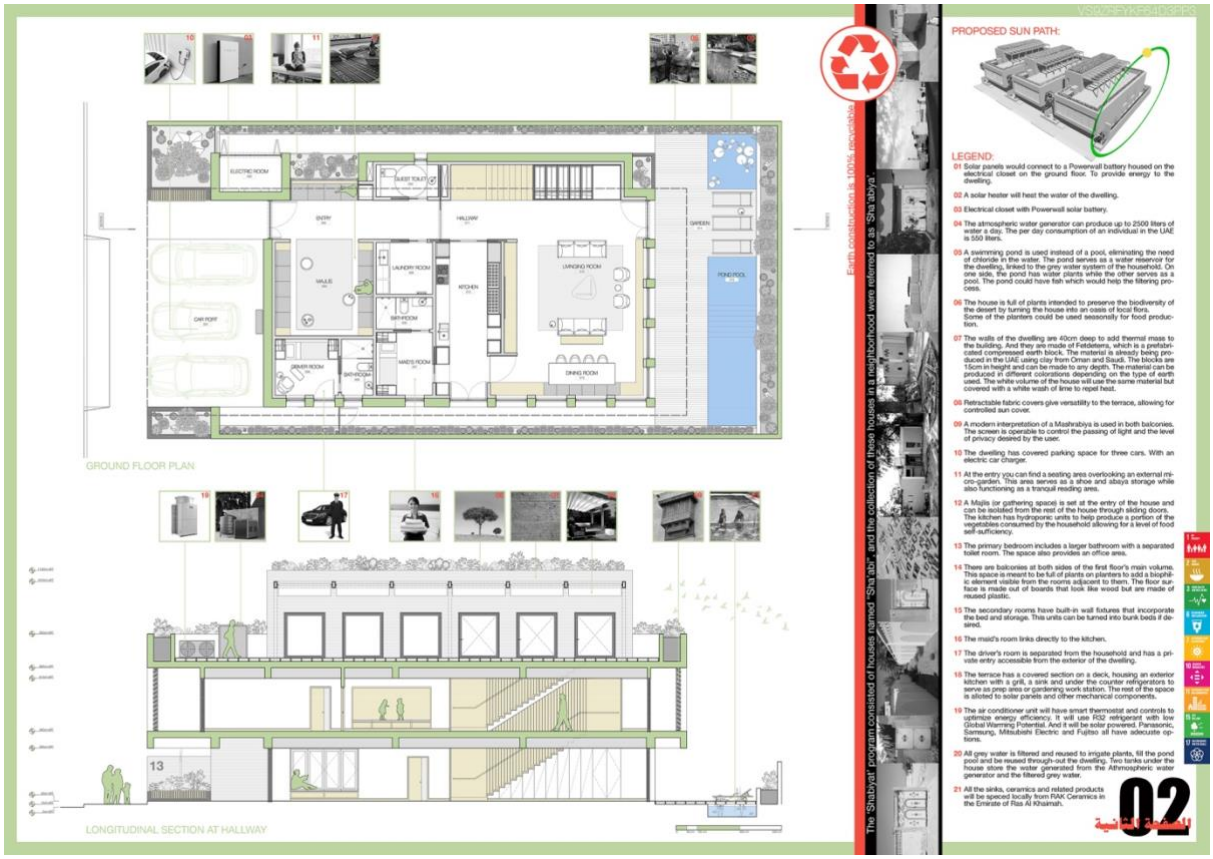
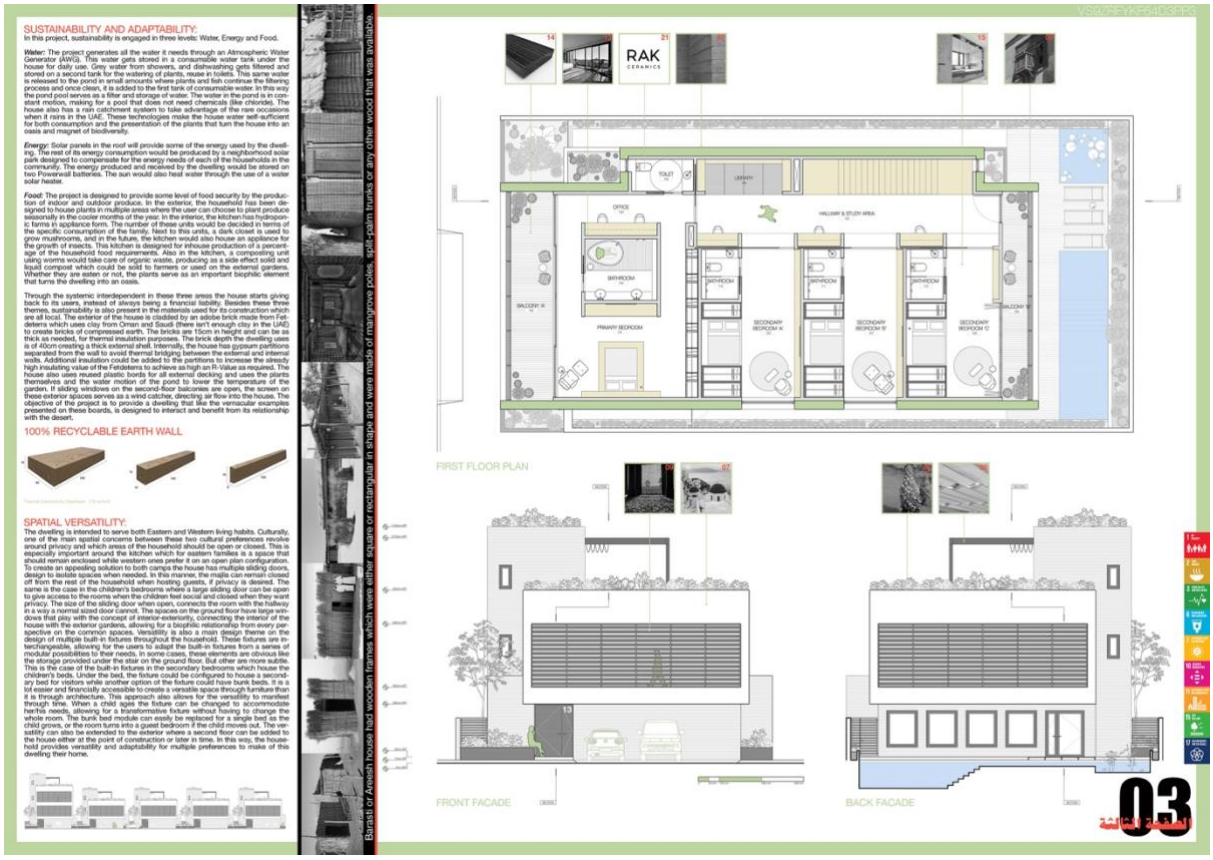


Figure 1. Implementation of vernacular ideas in contemporary design. Student Project by Nada Barqawi & Tala Alsakka Amini, ARC501.

Figure 2. Implementation of vernacular ideas in contemporary design.
Student Project by Penar Qanbar, ARC501.


ABSTRACT:
SHA'BI HOUSE 2.0-THE HOUSE OF THE PEOPLE
Emirati dwelling typologies from the Post-Nomadic period (up to 1793), the Traditional Period (1793-1945) and the Modern Period (1945- 1990).
WHY BUILD WITH EARTH?
Abundant in the region, earth is a 100% natural and recyclable resource. Earth masonry has a low carbon footprint because very little energy is used when constructing with it, which reduces its environmental impact. With a thermal mass optimal for indoor climate due to its capacity of heat regulation, the ability to manage humidity through the absorption and release of moisture, and its fire resistency due to being non-combustible, its a smart choice for the UAE!
WHAT IS A SHA'BI HOUSE?
01


PROPOSED SUN PATH:
LEGEND:
GROUND FLOOR PLAN
LONGITUDINAL SECTION AT HALLWAY
The 'Shabyat' program consisted of houses named "Sha'abi", and the collection of these houses in a neighborhood were referred to as 'Sha'abya'.
02



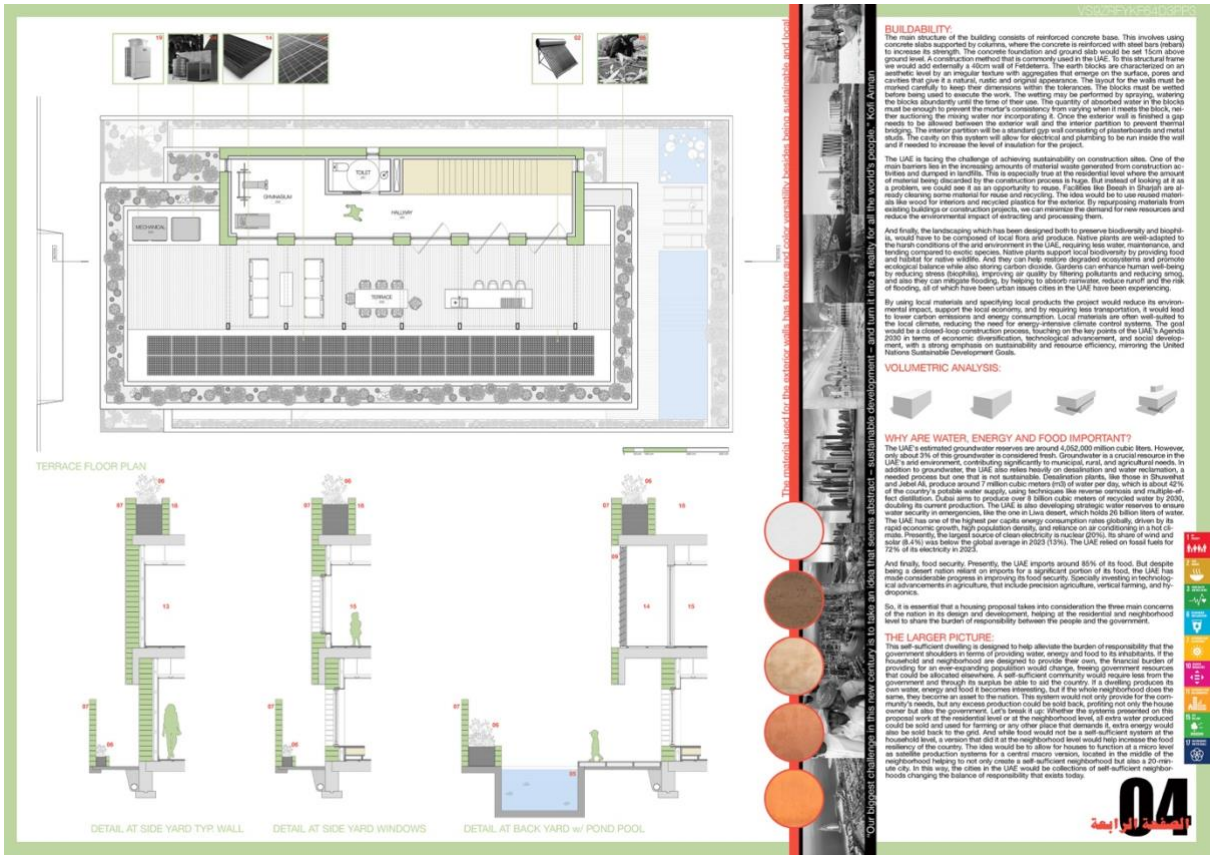


Figure 3. House of the Future Competition-2025. Project by Camilo Cerro.

This semester's program required designing a compound that multiple residents or a single extended, multi-generational family could inhabit. The original vernacular residential typology (local compound) was deconstructed and reinterpreted into a model that met the socio-cultural, environmental, and technological needs of the culturally diverse population in the Emirates today. Instead of creating privacy by enclosing the perimeter with a wall, landscape and screens were used for the same purpose, softening in this way the dwelling's relationship to the street. The buildings could not be higher than two levels and needed to be close enough to each other to shade areas of potential social interaction. Formally, most projects developed an understanding of sun paths, proximity of volumes for shade creation, the use of screens and landscaping as privacy generators, material thickness for thermal insulation, and cover as sun protection and temperature control. Socially, they investigated multi-generational living, rental units for passive income generation, and communal spaces designed for social interaction. Technologically, they focused on producing dwellings that benefit the user by conserving energy, water, and other resources, creating interdependent systems that aim at self-sufficiency (some examples of theoretical work can be seen in Figures 1 and 2). But the ultimate goal of the studio was to develop learners with agency, who start to work with sustainability as an inherent aspect of the design process, designers with social responsibility who understand the impact their work has on society.

The work produced during the semester was showcased to a group of government officials and local developers, aiming to spark a discussion about the future of dwelling in the UAE. At the same time, it sought to understand their perspectives, the reasons behind their approaches to residential development, and their thoughts on our ideas. They were very interested in the link to vernacular typologies because the government is currently searching for a design identity. They also responded positively to our focus on energy, water, and food, as these are themes that the government has been emphasizing as the UAE's population grows. The reviewers suggested that the proposed change in how infrastructure is utilized could be achieved by viewing neighbourhoods as independent entities, which sparked a discussion of the neighbourhood as a 20-minute neighbourhood. The research presented in this article was further implemented in a design for the 2025 House of the Future Competition, as shown in Figure 3. The proposal employed a similar design approach to the one followed in the studio, but with different parameters and a budget, program, and site set by the Ministry of Housing.

FINAL THOUGHTS

There is much to be learned from vernacular housing in the region that could improve how dwellings are designed and evolve in the UAE. The one thing that is proven not to work is the displacement of foreign typologies to a climate for which they were not designed. This displacement has led to problems such as resource waste, particularly in energy use, as well as issues with the cost and quality of living. While the region, rich in oil resources, can supply the population with energy, water, and food, it does so at a significant cost. This necessity creates an opportunity for a dwelling typology to begin mitigating these issues at the micro level (home), rather than only doing so at the macro level (urban). The work from the *Extreme Environment Studio* resulted in a series of dwellings that blended old and new ideas, utilizing modern technology and vernacular methods to address the necessity for better housing, providing sustainable solutions for the needs of a growing nation living in an extreme climate. Dwellings designed with local materials, utilizing renewable energy sources, producing their

own water, and featuring smart home technology that can automate tasks to make life easier, healthier, and more enjoyable. Self-sufficient homes aimed at reducing the burden of energy, water, and, to some extent, food production from the government, allowing those saved resources to be allocated to other national needs. These homes are designed for desert living, much like their vernacular counterparts from the past, demonstrating that the future of dwelling can support desert life by combining traditional knowledge with modern technology, enabling energy-efficient, culturally respectful, and economically sustainable designs that reduce environmental impact while meeting modern needs.

Acknowledgment

This research would not have been possible without the support of the College of Architecture, Art and Design at the American University of Sharjah and the Students who participated in the ARC501 studio held in the Fall of 2023; Manar Al Mohammedi, Lama Al Zubairi, Tala Alsakka Amini, Dhabia Alshamsi, Mariam Alsuwaidi, Nada Barqawi, Zainab Oghai Gawhari, Yousef Ibrahim, Syed Jagubar Jalal, Muhammad Joefrizal, Nadim Mourad, Ghayad Muhandes, Penar Qanbar & Yara Soliman.

NOTES

[1] Fatima Alsuwaidi, Reyhan Sabri & Vittorino Belpoliti, “Investigating the Values of Modern Architectural Heritage in Dubai, UAE,” *IOP Conference Series Material Science and Engineering*, 1203(2):022056 (2021). Accessed: June 17th, 2025. DOI:10.1088/1757-899X/1203/2/022056

[2] “UAE hits record May temperature of 51.6°C,” France 24, last modified: May 24, 2025. Accessed: June 17th, 2025. https://www.france24.com/en/live-news/20250524-uae-hits-record-may-temperature-of-51-6c

[3] Abdulaziz Alshabib, & Sam Ridgway, “Aramco and Al-Malaz Housing Schemes: The Origins of Modern Housing in Saudi Arabia,” *Histories of Postwar Architecture*, 5 (8), (2021): 147–166. Accessed: June 17th, 2025. https://doi.org/10.6092/issn.2611-0075/11738

[4] Ibn Khaldûn, “The Muqaddimah,” *The Anthropology of Climate Change: An Historical Reader*, First, (2014). Accessed: June 17th, 2025. https://onlinelibrary.wiley.com/doi/abs/10.1002/9781394260881.ch3

[5] J. E. Peterson, “Britain and state formation in the Gulf: The case of Abu Dhabi and Sheik Sayid Bin Khalifah,” *National Center for Documentation & Research*, November 25, 2008. Accessed: June 17th, 2025. http://www.jepeterson.net/sitebuildercontent/sitebuilderfiles/Peterson_Britain_and_Abu_Dhabi.pdf

[6] Abed Al-Razzak Al-Maani, & Saleh Alsharari, “Pearl Trade in the Persian Gulf during the 19th Century,” *Asian Culture and History*, 6(1) (2013). Accessed: June 17th, 2025. https://pdfs.semanticscholar.org/c703/2c77375f60fe6eb863a268ce3d5a2b48aa04.pdf

[7] Abdulkhaleq Abdulla, “Contemporary Socio-Political Issues of the Arab Gulf Moment,” *The center for the study of global governance*, September 2010. Accessed: June 17th, 2025. http://eprints.lse.ac.uk/55523/1/__lse.ac.uk_storage_LIBRARY_Secondary_libfile_shared_repository_Content_Kuwait%20Programme_Abdulla_2010.pdf

[8] Yasser Elsheshtawy, “The Emirati Sha‘bī House: On Transformations, Adaptation and Modernist Imaginaries,” *Arabian Humanities*, (2019): 11. Accessed: June 17th, 2025. http://journals.openedition.org/arabianhumanities/4185

[9] Abdulla Abdulkhaleq, “The Rise of the United Arab Emirates,” The Cairo Review of Global Affairs, last modified: Spring 2021. Accessed: June 17th, 2025. https://www.thecairoreview.com/essays/the-rise-of-the-united-arab-emirates/

[10] United Arab Emirates Ministry of Finance, “Federal General Budget Annual Report,” *United Arab Emirates Ministry of Finance*, (n.d.). Accessed: June 17th, 2025. https://mof.gov.ae/wp-content/uploads/2025/02/Federal-General-Budget-Annual-Report-2025.pdf

[11] Moncef Kra Krarti, & Kankana Dubey, “Review analysis of economic and environmental benefits of improving energy efficiency for UAE building stock,” *Renewable and Sustainable Energy Reviews*, 82, (2017): 14–24. Accessed: June 17th, 2025. https://www.sciencedirect.com/science/article/abs/pii/S1364032117312455?via%3Dihub

BIBLIOGRAPHY

Abdulkhaleq A. “The Rise of the United Arab Emirates.” The Cairo Review of Global Affairs, last modified: Spring 2021.

Abdulla, A. “Contemporary Socio-Political Issues of the Arab Gulf Moment.” *The center for the study of global governance*, September 2010.

Al-Maani, A. A., & Alsharari, S. “Pearl Trade in the Persian Gulf during the 19th Century.” *Asian Culture and History*, 6(1) (2013).

Alshabib, A. & Ridgway, S. “Aramco and Al-Malaz housing schemes: The origins of Modern housing in Saudi Arabia.” *Histories of Postwar Architecture*, 5(8), (2021): 147–166.

Alsuwaidi F., Sabri R. & Belpoliti V., “Investigating the Values of Modern Architectural Heritage in Dubai, UAE.” *IOP Conference Series Material Science and Engineering*, 1203(2):022056 (2021).

Elsheshtawy, Y. “The Emirati Sha‘bī House: On Transformations, Adaptation and Modernist Imaginaries.” *Arabian Humanities*, (2019): 11.

France 24. “UAE hits record May temperature of 51.6°C,” *France 24*, last modified: May 24, 2025.

Khaldûn, I. “The Muqaddimah.” *The Anthropology of Climate Change: An Historical Reader*, First, (2014): 55–66.

Krarti, M., & Dubey, K. “Review analysis of economic and environmental benefits of improving energy efficiency for UAE building stock.” *Renewable and Sustainable Energy Reviews*, 82, (2017): 14–24.

Peterson, J. E. “Britain and state formation in the Gulf: The case of Abu Dhabi and Sheik Sayid Bin Khalifah.” *National Center for Documentation & Research*, November 25, 2008.

United Arab Emirates Ministry of Finance. “Federal General Budget Annual Report.” *United Arab Emirates Ministry of Finance*, (n.d.).

BEYOND DEMOLITION: A RENOVATION-FIRST APPROACH TO 1960-1980 SCHOOL BUILDINGS IN STYRIA

Author:
ENA KUKIĆ

Affiliation:
Graz University of Technology

INTRODUCTION

Austria's ambition to achieve climate neutrality by 2040 necessitates a fundamental rethinking of how the built environment is managed, particularly in the public sector. Within this framework, a paradigm shift from new construction to renovation and adaptive reuse is crucial. However, as demonstrated by several notable cases of school architecture from the 1970s, structurally sound and socially embedded public buildings in Austria continue to be demolished or earmarked for demolition rather than considered for adaptation. Recognizing the school as a central public typology both in its societal function and cultural relevance this study investigates school buildings in Styria constructed between 1960 and 1980, a period characterized by rapid urban development and architectural innovation.

This paper draws on existing research, particularly the project *Schulen weiterbauen* by Maja Lorbek, which highlights the lack of consolidated data on public school buildings as a major barrier to strategic, long-term planning. As part of a foundational study conducted by the Institute of Construction and Design Principles at Graz University of Technology, this paper presents an initial dataset of the school building stock in Graz and Styria. This includes both preserved and demolished structures and forms the basis for future planning methodologies aligned with environmental and social sustainability goals.

An international reference is provided through the work of the Dutch Mevrouw Meijer Foundation, which has developed a strategy for assessing and upgrading school buildings from the same era. Their approach involves individualized research into each school, coupled with "research by design" collaborations with architects to create feasible renovation or adaptation options. Building upon these models, this study proposes strategies for the realistic valorisation and refurbishment of existing schools, exemplified through the School MS Bruckner in Graz as a pilot project.

By combining empirical research with a renovation-first argument framed within the Dutch example, the study emphasizes that maintaining and upgrading existing educational infrastructure can contribute to Austria’s climate and resource-efficiency goals, while also supporting social sustainability.

POLICY, CLIMATE TARGETS, AND THE CASE FOR ADAPTIVE REUSE

Transformative changes within the building sector which is responsible for approximately 34% of total energy consumption and 37% of greenhouse gas (GHG) emissions[1] are required to meet the European Union's commitment to climate neutrality by 2050. While regulations such as the Energy Performance of Buildings Directive (EPBD) have effectively promoted operational energy reductions, embodied carbon the emissions associated with the production, transportation, and disposal of building materials remains insufficiently addressed. As operational emissions decline, embodied carbon is projected to constitute 50-60% of the life-cycle emissions of new buildings by mid-century.[2]

Austria has adopted a more ambitious goal, aiming to reach climate neutrality by 2040. Yet between 2005 and 2023, the country achieved a 25% reduction in GHG emissions, which remains below the EU average of 30%.[3] In its Integrated National Energy and Climate Plan (NECP, August 2024), Austria has outlined a goal to renovate 3% of its state-owned building stock annually, with a specific focus on structures built between the 1950s and 1980s. This target reflects a growing awareness not only of energy performance but also of the architectural and cultural value of post-war buildings.

Adaptive reuse has gained prominence as a strategy to reduce embodied carbon while preserving architectural heritage. By repurposing existing structures, significant emissions from demolition and new construction can be avoided. Research indicates that circular economy strategies, including material reuse and recycling, could reduce embodied carbon by 30-40%.[4] Nevertheless, current life cycle assessment (LCA) methodologies often overlook the carbon savings from retaining existing building stock.

To meet the EU's 2050 climate neutrality target, the current renovation rate of approximately 1% per year must at least double by 2030. Policies need to move beyond energy performance standards and actively promote reuse strategies that consider both embodied and operational carbon. In this context, school buildings from the 1960s to 1980s represent a critical test case for implementing such an integrative approach.

THE SCHOOL AS AN ESSENTIAL PUBLIC TYPOLOGY: THE CASE OF STYRIA

School buildings are a central component of public infrastructure, embodying not only functional and educational roles but also social, architectural, and cultural values. In Styria, as in other Austrian regions, the post-war period witnessed a rapid expansion of school construction, particularly between 1960 and 1980. This era was characterized by standardized design principles and prefabricated construction methods aimed at addressing growing educational demands quickly and economically.

Two significant examples illustrate the ongoing threat to this architectural heritage: the demolition of the Gymnasium in Völkermarkt (Thurner and Uhl, 1974) in 2024 and the planned demolition of the school in Weiz (Viktor Hufnagl, 1973). These buildings emerged from the *Vorfertigung Schule* research initiative led by prominent Austrian architects, which experimented with modular construction and innovative educational layouts.

Figure 1. Mittelschule III Weiz by Schreyer David

By the early 1970s, school architecture in Austria had shifted toward compact, multi-story buildings, replacing the single-story pavilion schools of earlier decades. This was a direct response to economic pressures and rising student populations. Integrated school centres, which combined multiple school types within one building complex, became a dominant model.

However, the energy crisis of 1973 prompted a re-evaluation of these large-scale structures, ushering in a renewed focus on energy efficiency and architectural quality. Still, the typological innovations of the 1970s particularly the *Hallenschule* (hall school) and *Atriumschule* (atrium school)—continue to resonate in today's cluster school typologies.

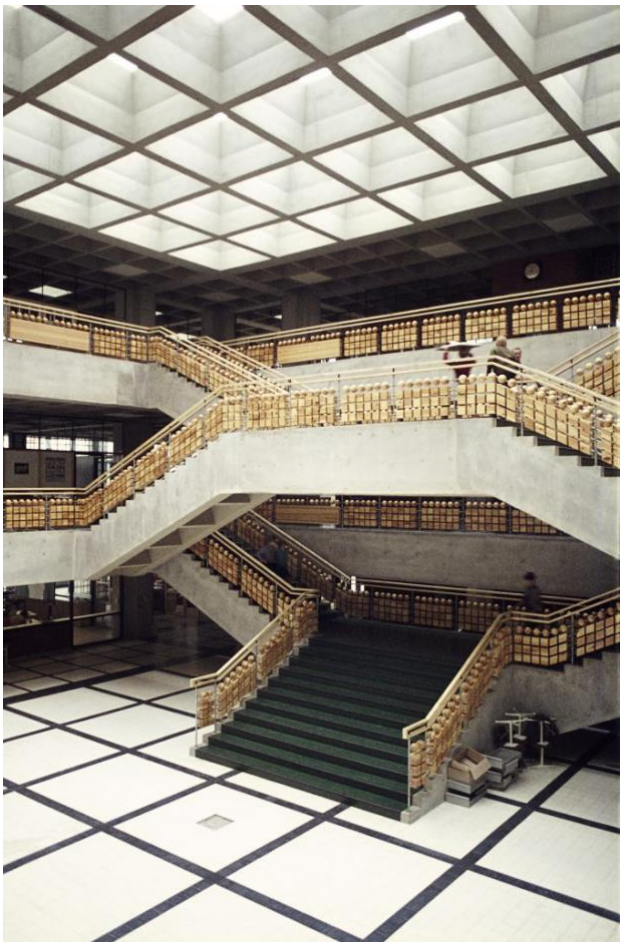


Figure 2. Mittelschule III Weiz by Architekturzentrum Wien, Sammlung, Foto: Friedrich Achleitner

Many of these buildings remain structurally sound and spatially adaptable. In an age of increasing student numbers and evolving pedagogical requirements, demolition has become a common response, often replaced by *Ersatzneubauten* (replacement buildings). Yet this approach conflicts with broader sustainability goals and often overlooks the architectural potential of existing school buildings. A shift toward renovation-first strategies is not only environmentally necessary but also architecturally and socially viable.

EXISTING RESEARCH AND IDENTIFIED GAPS

Despite the significance of the school building stock, research into sustainable renovation strategies for Austrian schools has been limited over the past two decades. The most comprehensive study to date is *Baustelle Schule – Nachhaltige Sanierungsmodelle für Schulen* (2011)[5], which developed models for sustainable school refurbishment. While the study provides valuable data and includes case studies, it stops short of offering detailed design adaptations or scalable planning tools.

Another initiative, *RENEW SCHOOL Austria*[6], focused on the practical and financial aspects of school renovations, drawing insights from 14 exemplary projects. These included effective cooperation models among stakeholders and were disseminated through a publicly accessible brochure. This work contributed to broader EU-level efforts through the IEE project *RENEW SCHOOL*.

The more recent research project *Schulen weiterbauen*[7], led by Maja Lorbek, forms a critical foundation for this paper. Lorbek outlines scenario development as a strategic planning tool and presents multiple scenarios for the evolution of school infrastructure. She identifies two key research gaps: the lack of aggregated, evaluated data on the existing school building stock, and the need to explore the complex relationship between spatial design and educational outcomes.

Lorbek further advocates for a portfolio-based approach to research and planning, emphasizing the importance of broad, comparative analysis over isolated case studies. This comprehensive perspective is essential for formulating long-term, strategic interventions that align with both environmental targets and educational needs.

Taken together, these projects highlight the growing recognition of schools as critical public assets. However, the gaps identified particularly the lack of systematized data and scalable design strategies remain significant barriers to the widespread adoption of renovation-first approaches in Austria's educational infrastructure.

BUILDING STOCK DATABASE: A FOUNDATION FOR STRATEGIC PLANNING

In the initial phase of this study, the KOEN Research Group, in collaboration with key institutional partners Graz Building Management Authority (GBG), Bundesimmobiliengesellschaft (BIG), and the Referat für Bildung undertook foundational research to establish a comprehensive overview of the school building stock in Graz. This work resulted in the development of the *School Building Stock Database for Graz*, which systematically records the physical, temporal, and typological characteristics of the city's educational infrastructure.

Although the primary geographic focus is Graz, the database contextualizes local findings within broader national trends in Austrian school construction between 1960 and 1980. It also includes data on buildings that have been demolished, repurposed, or left vacant, revealing patterns of underuse and disappearance often obscured by fragmented or inaccessible records. The absence of consolidated information on demolition and vacancy trends presents a significant barrier to informed planning. Addressing this deficit is essential for the development of circular strategies in the education sector.

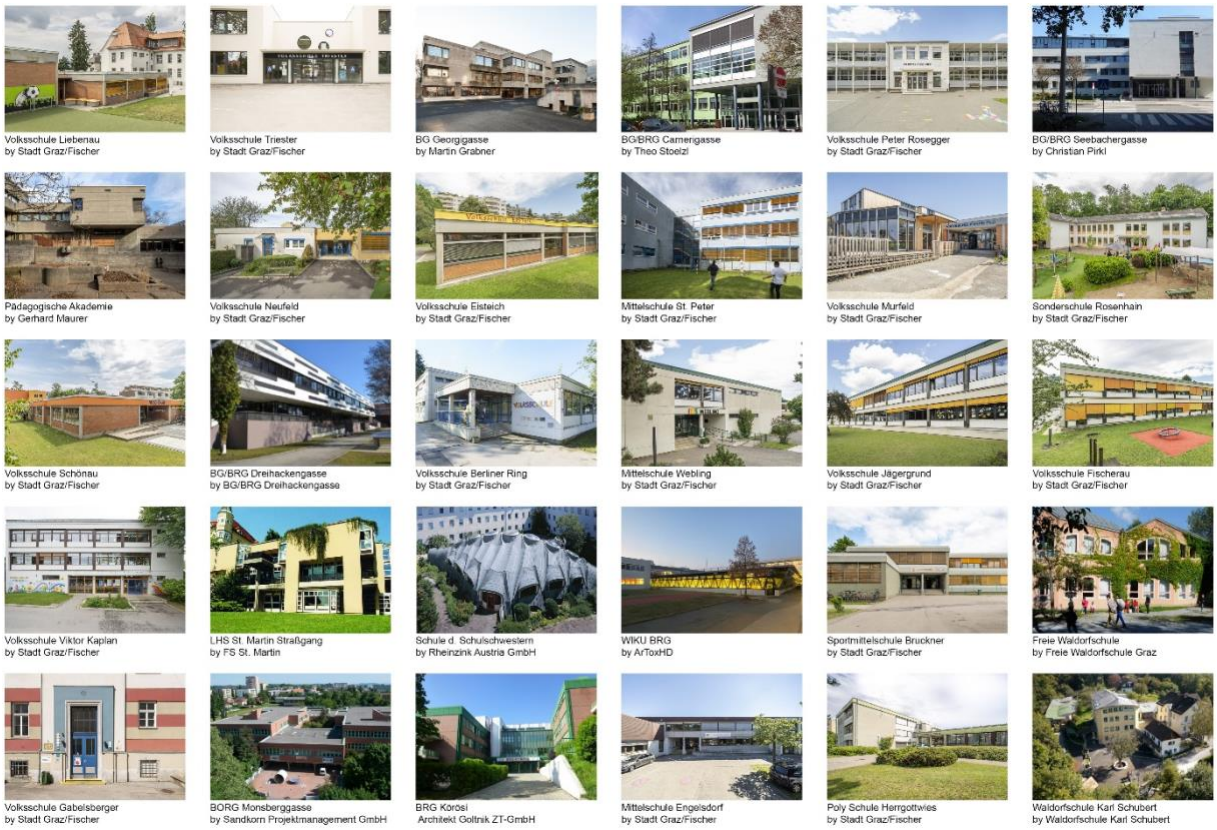


Figure 3. Overview of school buildings (1960s-1980s) in Graz, collage by KOEN Research Group

The dataset captures both active (currently operational) and inactive (altered, abandoned, or replaced) components of the school building stock. It directly responds to the gap identified by Maja Lorbek specifically, the lack of systematically aggregated and evaluated data required for strategic planning in educational infrastructure.

Data have been structured into multiple tables, providing insights into typology, construction period, usage, and refurbishment status. Analysis reveals that school buildings constructed between the 1960s and 1980s represent approximately 40% of the total stock (ranked by the number of classes per school), encompassing a diverse range of school types. Notably, more than half of these buildings are in need of refurbishment and face the risk of obsolescence if proactive measures are not implemented.

This data-driven foundation supports the subsequent phases of the study, including qualitative and design-based analyses. It also offers a replicable framework for other municipalities aiming to align educational infrastructure planning with sustainability and circular economy goals.

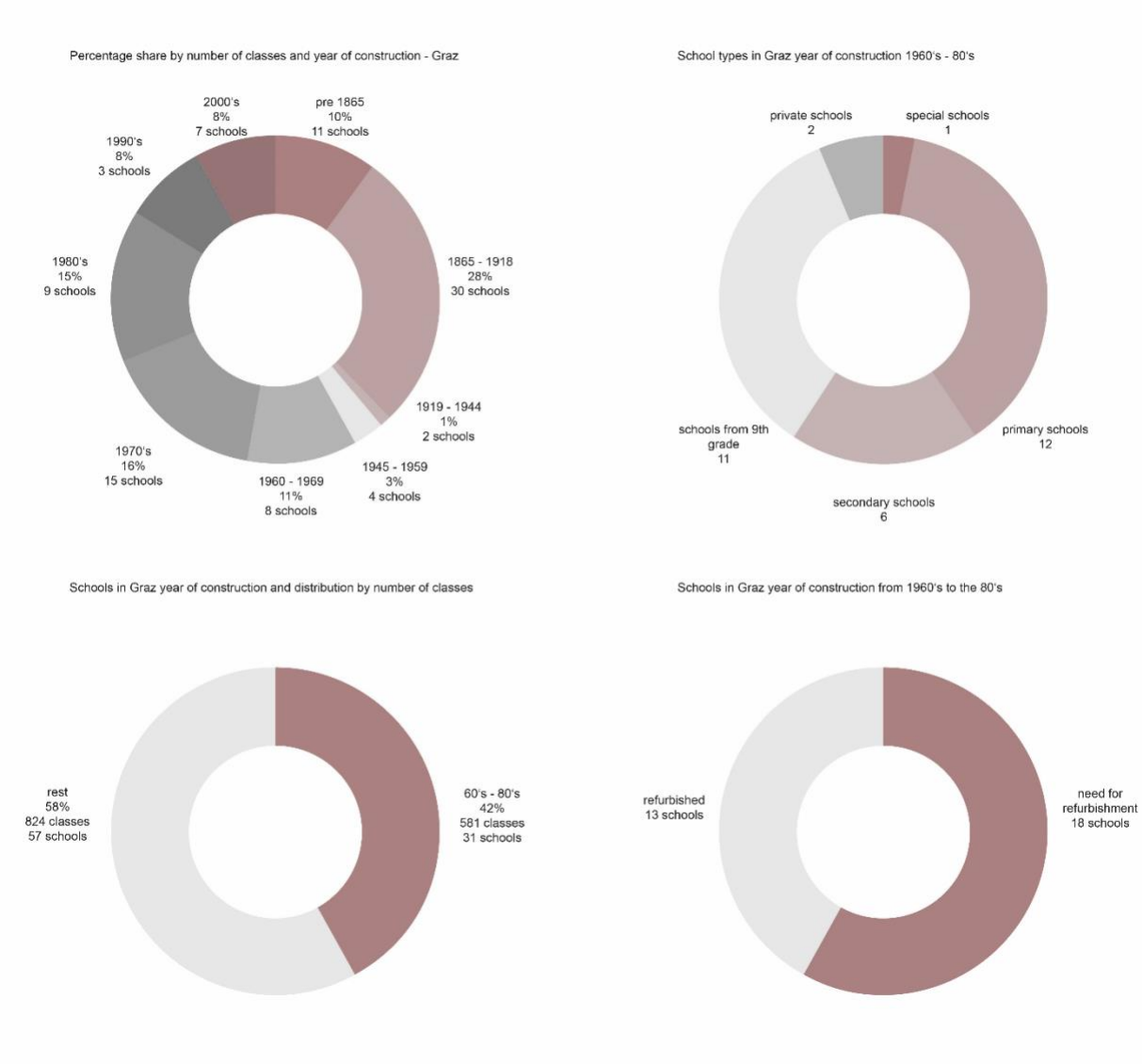


Figure 4. Some key findings from the School Building Stock Database by KOEN Research Group

INTERNATIONAL BEST PRACTICE: MEVROUW MEIJER AND THE CASE FOR CONTINUED USE

A critical best-practice reference for the reuse and continued operation of existing school buildings comes from the Netherlands, where the Mevrouw Meijer Foundation has developed a highly structured, design-led approach to school renovation. Founded as an idealistic research agency, Mevrouw Meijer is grounded in the belief that schools are more than utilitarian infrastructure they are formative environments for learning, community, and civic identity. Their work frames school architecture as a public and cultural good that deserves care, creativity, and long-term thinking.[8]

Since 2004, Mevrouw Meijer has developed and refined a methodology for assessing, renovating, and reinvigorating aging school buildings, particularly from the 1960s and 1970s. Rejecting the widespread narrative that contemporary education cannot fit into buildings of the past, the foundation treats renovation as a serious architectural task. Their process is rooted in rigorous research and

stakeholder engagement, culminating in what they term a “Five Step Plan” that unfolds over six months. It involves both technical analysis and spatial imagination, with architectural firms working not in competition but in dialogue to propose diverse, high-quality design solutions for continued school use.

Mevrouw Meijer focuses on the ‘ordinary’ schools non-iconic buildings that are structurally sound and programmatically flexible. The method emphasizes the continued use of school buildings (as opposed to “reuse” or adaptive transformation into non-school functions), though hybrid scenarios are also considered in response to demographic shifts, such as in rural areas.

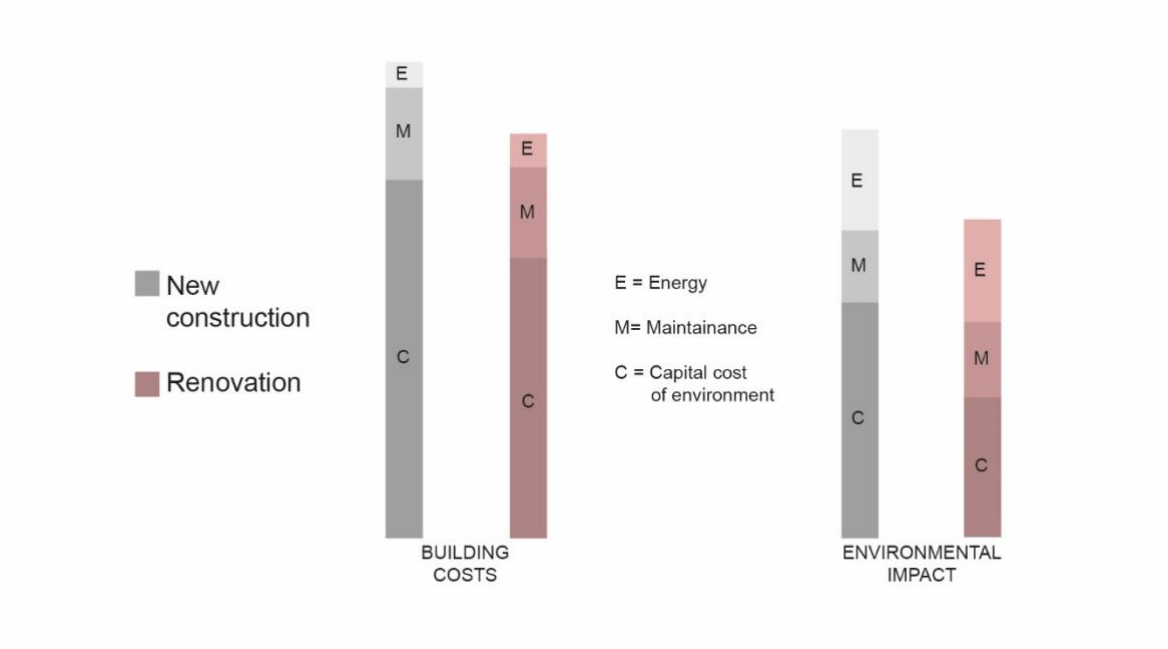


Figure 5. Comparison of building costs and environmental impact in new construction versus renovation by Mevrouw Meijer, visualized by KOEN Research Group

Central to their approach is the Eco Quaestor tool, implemented in partnership with technical consultant Winket. It allows the calculation of various renovation and new-build scenarios, taking into account not just cost but also life-cycle carbon emissions in line with the NEN-EN 15978 standard. Winket assesses scenarios ranging from technical upgrades without spatial changes (“zero option”) to full demolition and speculative new construction. These are contrasted with design proposals that integrate spatial and programmatic renewal with existing structures.

Architects are invited to participate as spatial researchers selected for their analytical mindset and inexperience with school design, to ensure fresh thinking. Through a process of kick-off workshops, interim presentations, and final feedback loops with all stakeholders (from teachers and students to urban planners and municipal officials), three divergent but complementary design visions are developed. Rather than delivering a single “solution,” the output is a curated spectrum of possibilities, all supported by financial and ecological analysis.

Mevrouw Meijer does not operate within a typological framework, nor does it promote standardized architectural solutions. Its innovation lies in a standardized process one that is robust, communicative, and transferable. While the governance context in the Netherlands, with decentralized school planning

across 342 municipalities, differs from that of Austria, the model remains adaptable. Its core strength is in making the existing visible and valuable, especially at a time when the construction sector must pivot toward more sustainable practices.

Though still modest in numerical reach, Mevrouw Meijer's influence is growing through successful examples like the award-winning Nimeto vocational school in Utrecht and primary school Molenwiek Dalton in Haarlem. Their approach offers clear implications for Austria and beyond: namely, that qualitative design, environmental accountability, and broad participation can create compelling alternatives to demolition. As the urgency of the climate crisis escalates, such process-based models become not just relevant but necessary.

Figure 6. Before and after - primary school Molenwiek Dalton in Haarlem by Korth Tielens

PROPOSAL FOR VALORIZATION IN STYRIA: PILOT STUDY – SPORT MS BRUCKNER, GRAZ

Amid rising pupil numbers in Styria, municipalities face increasing pressure to provide additional educational infrastructure. In many cases, this has led to a pattern of new school construction on available land, often sidelining the potential of existing buildings. However, the pending relocation of the Sport MS Bruckner school in Graz by 2028 presents a timely opportunity to explore an alternative approach one that aligns with climate objectives, urban consolidation, and architectural reuse.

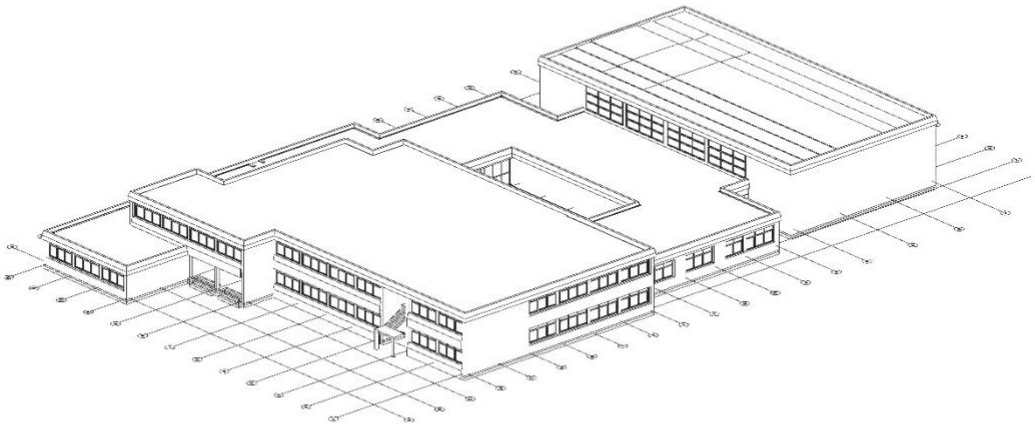


Figure 7. Model preview of Sport MS Bruckner school in Graz, by KOEN Research Group

Built in 1980, the existing Sport MS Bruckner is a compact, large-scale structure characteristic of the prefabricated school architecture of its time. Situated adjacent to the Inffeldcampus of TU Graz, the site holds strategic value for the university's expansion. With the school vacating the premises in 2028, the moment is ideal to initiate a structured valorisation process, positioning this site as a pilot project for sustainable redevelopment in Styria.

The proposed approach follows a three-step framework:

1. Life-Cycle Assessment (LCA):
A comprehensive LCA should be conducted on the existing building, focusing on both embodied energy and the projected greenhouse gas (GHG) emissions resulting from full demolition. This establishes a baseline for understanding the environmental costs of the default demolition-rebuild pathway (Ersatzneubau).

2. Typological Matches Assessment:
Multiple scenarios for reusing the existing structure should be developed along a gradient of intervention:

- Scenario 1 - Minimum Intervention: Retain the existing layout and structure, implementing only essential technical upgrades and safety improvements.

- Scenario 2 - Typological Continuity: Adapt the building to remain within the school typology, supporting new pedagogical concepts (e.g., flexible learning environments, inclusivity, co-use).
- Scenario 3 - Typological Transformation: Convert the building into an entirely new use (e.g., student housing, community center, innovation labs) while preserving as much of the existing structure as possible.

3. Scenario-Based GHG Comparison:
Each scenario, including the speculative new-build alternative, will be evaluated using standard CO_2 accounting methodologies. This creates a quantitative decision-making matrix that combines environmental and spatial outcomes. Visualizing the spectrum of options reveals the best-case scenario, both in terms of sustainability and programmatic fit.

The Sport MS Bruckner case thus becomes a laboratory for strategic transformation, offering broader implications for school valorisation across Styria. By beginning with a methodical, research-led approach rather than defaulting to demolition, the project can generate clear insights into long-term value creation, supporting a regional shift toward circular, climate-aligned architectural practice.

CONCLUSION

The transformation of existing school buildings is no longer a marginal concern it is emerging as a critical architectural and environmental task of the 21st century. This report has demonstrated that reuse and continued use of school infrastructure is not only viable but often preferable when considering life-cycle emissions, social continuity, and spatial potential. Drawing from best-practice models such as Mevrouw Meijer in the Netherlands, we observe a growing capacity for integrative and participatory renovation strategies.

In Styria, the convergence of rising demand for school space and a growing stock of aging buildings provides fertile ground for developing new methodologies. The proposed Sport MS Bruckner pilot project exemplifies how structured assessment combining life-cycle analysis, typological scenario planning, and stakeholder engagement can guide a more responsible and adaptive form of urban and educational development.

What is required now is policy support, institutional readiness, and architectural imagination. Valorisation must become standard procedure not an exception. Only then can educational infrastructure become a model of resource-conscious, user-cantered, and climate-resilient design.

The tools and knowledge are available. The urgency is clear. What remains is a commitment to act and to value what we already have.

Acknowledgment

The research underlying this article was conducted collaboratively by the KOEN Institute (Institute for Construction and Design Principles, Graz University of Technology). In addition to the author, the team included Petra Petersson, Ajna Babahmetović, David Ortner, Barbara Gruber, Victoria Pirker, Stefan Hochhofer, Hannah Gilly, and Vic Schmitz.

NOTES

[1] United Nations Environment Programme. *Global Status Report for Buildings and Construction: Beyond Foundations.* Nairobi: UNEP, 2024. https://doi.org/10.59117/20.500.11822/45095 (accessed April 26, 2025).

[2] European Parliament. *Austria's Climate Action Strategy.* Brussels: European Parliament, 2024. www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2024)767170 (accessed April 12, 2025).

[3] World Business Council for Sustainable Development and Arup. *Net-Zero Buildings: Where Do We Stand?* 2021. https://www.wbcsd.org/wp-content/uploads/2023/10/Net-zero-buildings-Where-do-we-stand-.pdf (accessed May 14, 2025).

[4] Maduta, C., G. Melica, D. D'agostino, and P. Bertoldi. *Defining Zero-Emission Buildings: Support for the Revision of the Energy Performance of Buildings Directive.* Luxembourg: Publications Office of the European Union, 2023. https://doi.org/10.2760/107493.

[5] Haseltsteiner, M. *SchulRen+: Nachhaltig Wirtschaften.* Baustelle Schule, 2011. https://nachhaltigwirtschaften.at/resources/hdz_pdf/berichte/endbericht_1247_schulren.pdf (accessed April 15, 2025).

[6] RENEW SCHOOL. *Innovative Finanzierung und Sanierung von Schulgebäuden.* 2018. https://nachhaltigwirtschaften.at/resources/hdz_pdf/berichte/endbericht_1723_renew-school.pdf (accessed April 15, 2025).

[7] Lorbek, M. *Schulen Weiterbauen: Strategische Entwicklung von Schulgebäudebeständen.* Bielefeld: transcript Verlag, 2020.

[8] Mevrouw Meijer. "About Mevrouw Meijer." n.d. https://www.mevrouwmeijer.nl/en/about/ (accessed April 5, 2025).

BIBLIOGRAPHY

Alaux, N., B. Schwark, M. Scherz, M. R. M. Saade, and A. Passer. "Parameters Influencing the Prospective Life Cycle Emissions of the Austrian Building Stock: A Global Sensitivity Analysis." *Sustainable Production and Consumption* 56 (2025): 618–631. https://doi.org/10.1016/j.spc.2025.04.024.

Böhme, J., ed. *Schularchitektur im Interdisziplinären Diskurs: Territorialisierungskrise und Gestaltungsperspektiven des Schulischen Bildungsraums.* Wiesbaden: VS Verlag für Sozialwissenschaften, 2009.

Bundesministerium für Bildung, Wissenschaft und Forschung. *Schulbau Rahmenbedingungen – SCHEP 2020.* n.d. https://www.bmb.gv.at/Themen/schule/schulsystem/schulbau/schep2020.html (accessed April 5, 2025).

Federal Ministry for Sustainability and Tourism. *Integrated National Energy and Climate Plan for Austria 2021–2030.* Vienna: Federal Ministry for Sustainability and Tourism, 2019. https://energy.ec.europa.eu/system/files/2020-03/at_final_necp_main_en_0.pdf (accessed May 2, 2025).

Haseltsteiner, M. *SchulRen+: Nachhaltig Wirtschaften.* [PDF] Baustelle Schule (2011). https://nachhaltigwirtschaften.at/resources/hdz_pdf/berichte/endbericht_1247_schulren.pdf (accessed April 15, 2025).

Hoppe, D. S. *Schulbau in Österreich: Eine Qualitative Bestandsaufnahme 1996; Eine Studie im Auftrag des Bundesministeriums für Unterricht und Kulturelle Angelegenheiten.* Wien: VÖ, 1996.

Hufnagl, V. *Vorfertigung im Schulbau. Schlussbericht: Ergebnisse, Feststellungen, Empfehlungen.* Wien, 1971.

Huuhka, S., M. Moisio, E. Salmio, A. Köliö, and J. Lahdensivu. "Renovate or Replace? Consequential Replacement LCA Framework for Buildings." *Buildings & Cities* 4, no. 1 (2023): 212–228. https://journal-buildingscities.org/articles/10.5334/bc.309 (accessed May 16, 2025).

Kempinga, W. Interview by E. Kukić. Online, June 25, 2025. Unpublished research interview.

Lorbek, M. *Schulen Weiterbauen: Strategische Entwicklung von Schulgebäudebeständen.* Bielefeld: transcript, 2020. [Doctoral thesis]

Mevrouw Meijer. “About Mevrouw Meijer.” n.d. https://www.mevrouwmeijer.nl/en/about/ (accessed April 5, 2025).

Nehrer, M., and Österreichisches Institut für Schul- und Sportstättenbau. *Schulbau in Österreich von 1945 bis Heute.* Horn, Wien [u.a.]: Berger, 1982.

RENEW SCHOOL. *Innovative Finanzierung und Sanierung von Schulgebäuden.* [PDF] 2018. https://nachhaltigwirtschaften.at/resources/hdz_pdf/berichte/endbericht_1723_renew-school.pdf (accessed April 15, 2025).

Rettich, S., S. Tastel, N. Beucker, A. Schmidt, C. Alexander, A. Batista, M. Gantert, and J. Siedle. *Obsolete Stadt: Raumpotenziale für eine Gemeinwohlorientierte, Klimagerechte und Ko-Produktive Stadtentwicklungspraxis in Wachsenden Großstädten.* Kassel: Universität Kassel, 2023. https://obsolete-stadt.net/bericht/ (accessed February 5, 2025).

Röck, M., M. R. M. Saade, M. Balouktsi, F. N. Rasmussen, H. Birgisdottir, R. Frischknecht, G. Habert, T. Lützkendorf, and A. Passer. “Embodied GHG Emissions of Buildings – The Hidden Challenge for Effective Climate Change Mitigation.” *Applied Energy* 258 (2020): 114107. https://doi.org/10.1016/j.apenergy.2019.114107.

School Building Stock Database for Graz. *KOEN Research Group, TU Graz, Graz,* 2025.

United Nations Environment Programme. *Global Status Report for Buildings and Construction: Beyond Foundations: Mainstreaming Sustainable Solutions to Cut Emissions from the Buildings Sector.* Nairobi: UNEP, 2024. https://doi.org/10.59117/20.500.11822/45095 (accessed April 26, 2025).

World Business Council for Sustainable Development and Arup. *Net-Zero Buildings: Where Do We Stand?* 2021. https://www.wbcsd.org/wp-content/uploads/2023/10/Net-zero-buildings-Where-do-we-stand-.pdf (accessed May 14, 2025).

Zimmermann, R. K., Z. Barjot, F. N. Rasmussen, T. Malmqvist, M. Kuittinen, and H. Birgisdottir. “GHG Emissions from Building Renovation versus New-Build: Incentives from Assessment Methods.” *Buildings & Cities* 4, no. 1 (2023): 274–291. https://journal-buildingscities.org/articles/10.5334/bc.325 (accessed May 16, 2025).

BEYOND THE 3D MODEL: HOW VIRTUAL RECONSTRUCTION SUPPORTS THE PRESERVATION OF HERITAGE THROUGH PARADATA.

Author:
PANAGIOTIS PAPAGEORGIOU

Affiliation:
UNIVERSITY OF PORTSMOUTH

INTRODUCTION

Computer graphics techniques such as 3D modelling and laser scanning are present in every step of the archaeological research, from survey, excavation, and analysis to reconstruction, synthesis and communication. This computerisation of archaeological datasets offers new exploitation possibilities, like the immediate connection of different kinds of data for analyses. Nevertheless, the new data reuse opportunities, achieved by the digital transformation of the archaeological domain, require the systematic recording of the digital documentation around a virtual reconstruction to understand what it represents. This paper suggests that additional documentation explaining how the multidisciplinary research project team reached their decisions during the creative design process (virtual reconstruction paradata) is also required to support the scientific authenticity as well as the repeatability of, often, particularly expensive, and difficult to reproduce proprietary processes. An archaeological virtual reconstruction, together with its virtual reconstruction paradata, may be valuable as a historic document in its own right rather than as an example of archaeological evidence. Hence, this research article argues that if this is extended to digital preservation, it becomes imperative to maintain the original data alongside full documentation of the creative design process because that may have greater long-term reuse potential than the final produced output of an archaeological research project. It is clear that the focus is not on the importance of the digital file but the history that it represents. Thus, the value of a virtual reconstruction is in the surrounding context, not just the 3D object itself.

DIGITAL TRANSFORMATION

The adoption of computers for analysing the material (finds) archives further developed the field of archaeology.[1] The advent of computer graphics allowed archaeologists to shape alternative readings of their evidence,[2] e.g., examination of the interplay of light within a social space, comparison of different structures and extrapolation of the interior decoration of a certain architectural type. Admittedly, the act of 3D modelling constitutes a form of knowledge representation where different data types, i.e., archaeological, historical, topographical, architectural, geological, environmental, and textual, are combined in a single representation.[3] This integration of knowledge into a single medium permits archaeologists to avoid interpretative pitfalls and convey their interpretations to non-specialists. As early as the end of the late 1980s, the explicit interpretation of the archaeological process through a

transparent and organised manner as well as the generation of research questions that otherwise would be impossible to be elicited were seen as some of the many benefits the introduction of computers into archaeology could offer.[4] Computer-generated models can also be used as useful tools for training young archaeologists in modern excavation techniques without having to destroy the archaeological record.

Whilst archaeological finds can be recorded in a digital format for future generations when it is not possible to preserve the original artefact, the Archaeology Data Service (ADS) Strategies for Digital Data reported that: "The archaeological record could be decaying faster in its digital form than it ever did in the ground."[5] The latter issues may be caused by the fragmentation of the field of archaeological preservation. This means that the standards involved are not unified, and as no one organisation has control of the process, there is no control of the storage of, and access to, archaeological data. This is due to the different 'actors' responsible for different aspects of the archaeological work: Archaeologists, 3D creatives and the public. This lack of a uniform process to get from the archaeological excavation site to a digital repository, and eventually to the future user, highlights the need for preservation metadata standards as well as understanding of the different roles of the designated communities involved.

SCIENTIFIC AUTHENTICITY

An archaeological research project usually consists of a documentary archive, e.g., CAD files, databases, spreadsheets and 3D data, and a material (finds) archive, e.g., artefacts, building materials and environmental remains. Every project of that nature must ensure the security, stability, accessibility as well as the order of its archives. All of the above prerequisites could be satisfied by using, for example, accepted standards in file naming and recognised terminology.[6]

Typically, archaeological virtual reconstructions have used established visual conventions during production, such as blurring, transparency, and false colouring, to depict those parts of the 3D models with uncertain features.[7] However, this is an important element of paradata (i.e., information about the research process)[8] that needs to be preserved for all archaeological research projects, as it could be missing from the final published virtual reconstruction. While proposed visual conventions, such as non-photorealistic (sketch-like) rendering, aim to represent uncertainty in archaeological virtual reconstructions,[9] they are not yet an established standard. As a result, not all virtual reconstructions contain this paradata. Moreover, these conventions only preserve elements of uncertainty, and not the archaeological decisions embedded within the creative design process (i.e., the set of explicit and implicit choices made by 3D creatives, such as computer modelers, based on both the data and interpretive decisions). These choices shape how the physical environment or object is digitally rendered, significantly influencing the final understanding of the reconstruction. Ideally, these decisions are made collaboratively within a team, often involving experts from various disciplines, and are

particularly crucial when working in geographically distributed teams. A central individual or team should oversee the 3D models and associated paradata, while consulting experts contribute their domain-specific knowledge. The creative design process thus includes not only the technology used to digitise cultural heritage, but also the interpretive steps taken in transforming raw data into a virtual representation.

However, in the final published version, archaeological sites are typically represented as photo-realistically (homogeneously) as possible, which means the paradata (specifically the degree of uncertainty and the decisions made during the creative design process) often remains confined to the original production files, rather than being embedded in the final visualisations. Consequently, the file most likely to be preserved is the one with the least information about how a certain virtual reconstruction was created.

Therefore, it is suggested that alternative interpretations should be preserved as part of the required paradata accompanying a specific final artefact. However, this may not be practical in the context of small-scale archaeological research projects due to the lack of digital preservation capacity building, especially as they would not be 'used' in any published context. This suggests the importance of considering the designated community for each final research output, including the alternative reconstructions, as well as the responsibility of different roles for the effective preservation of different aspects of an archaeological research project's digital record.

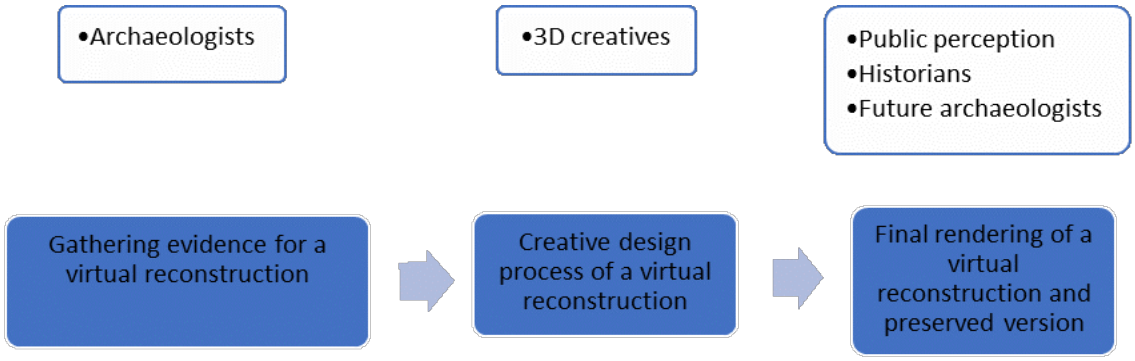


Figure 1. The process and agents involved in the production and 'consumption' of a virtual reconstruction.

Thus, the archaeological community should seek to deploy 'agreed in advance' standards and processes, as well as record the archaeological methodology (i.e., archaeological paradata). Respectively, 3D creatives (e.g., 3D reconstruction specialists) should include explicit and implicit decisions based on the data in the 3D reconstruction files. Every archaeological research project must ensure the scientific transparency, reproducibility, reusability as well as the accessibility of its records. These requirements

could be supported, for example, through targeted 3D scene management,[10] i.e., automated selection (hiding and unhiding) of 3D objects with different levels of uncertainty.

None of the above suggestions are explicit in the preservation metadata standards, although some are implicit in the archaeological reconstruction standards. For example, Principle 7 of the Seville Charter,[11] and similarly the London Charter,[12] touches on the need for scientific transparency. Particularly, it covers the significance of transparent and validated methodological approaches for the evaluation and reproducibility of costly and time-consuming multidisciplinary research processes,[13] i.e., only repeatable within a specific software package, with access to the archaeological decisions made at that specific time.

This is indicative of the important requirement for the preservation of the contextual information pertinent to the creative design process of any given 3D object, as a form of metadata which records the creative design process. For a virtual reconstruction to be 'scientifically authenticated,' i.e., transparent and validated methodological approach, both its archaeological paradata (i.e., a record of the archaeological process) and virtual reconstruction paradata needs to be associated.

CONTEXTUAL METADATA

Given that the concept of the designated communities is fluid and it is uncertain which properties of a digital object future users might consider significant, the need arises for preservation of information about the intellectual content, what Anderson et al.[14] call "significant properties," of a given digital object is needed so that future generations can understand the meaning of what they see or hear, and eventually use. Thus, at a minimum, effective digital preservation has two parts: 1) Renderability (the ability to 'execute' and use a stored digital object), and 2) Understandability (the ability to interpret and understand the given object).[15] Hence, even at the minimum level, it is not sufficient to preserve only media and bits, as additional data is required for Understandability.

Returning to the concept of Understandability, the 'significant properties' of a digital object are needed so that future users can interpret and understand it. Wilson[16] defines these as "the characteristics of digital objects that must be preserved over time in order to ensure the continued accessibility, usability, and meaning of the objects, and their capacity to be accepted as evidence of what they purport to record." However, the meaning and significance of an information object are highly dependent on its

spatial and temporal context. As the data evolves across different phases of the information lifecycle, discipline and societal changes lead to their 'semantic decay,' e.g., due to changes in use of terminology. A key issue is the provision of sufficient contextual information to enable both lifecycle management and preservation on the one hand, and reuse and reinterpretation of content on the other. Records and archives derive meaning and value from a myriad of contextual relationships that need to be understood and documented.[17]

DIGITAL INTERPRETATION

Although very much a subjective topic, the interpretation of an archaeological monument at the moment of its virtual reconstruction should potentially expand the relevant metadata fields that need to be recorded. As large volumes of new digital archaeological outputs constantly emerge, this can lead to their preservation being inconsistent with current best preservation practice, i.e., basic uncontextualised storage only. As a result, the majority of the stored archaeological virtual reconstructions do not really have much context. It thus seems that they have lost their values as digital archaeological objects. However, they might still have some cultural or social significance but only if they are preserved correctly. Thus, in addition to a preservation strategy, it is clear that this strategy should be based on keeping the digital objects in as 'original' a format as possible, to preserve their cultural significance of that digital age, as well as the archaeological information that they contain. Examining the evolution of the archaeological virtual reconstructions through the years, i.e., their social context, is something that may be of particular scientific value for the digital preservation community.

The available contextual information (archaeological metadata and virtual reconstruction paradata) along with the final artefact/visualisation itself (the version released after the completion of an archaeological research project) affects the perception of the monument at any given time. Contextual information, such as the geographical location of a monument, can be included into the 3D file itself, e.g., in the form of a georeferenced 3D model. This could be tracked over time, and when combined with new archaeological findings might lead to alternative reconstructions. In this case, a preserved archaeological virtual reconstruction manages to document not only the current cultural understanding of 'the data', but also the state of technology used to generate it (thus preserving the limitations of knowledge as well). Therefore, this historical context should also be recognised as an important aspect of the selected preservation strategy.

In turn, the discovery of new archaeological information, when combined with contemporary high-fidelity rendering techniques (physically based rendering, ray tracing, or real-time game engines),[18] can also change the perception of a monument. These techniques, while subject to rapid technological obsolescence, are significant not only for their interpretive impact but also as representations of the aesthetic value of a 3D object at the time of its creation. For instance, the Antikythera Mechanism[19] has been digitally reconstructed numerous times over the past two decades, with each version reflecting both new archaeological and scientific discoveries and the visualization technologies available at the time. Its trajectory has progressed from early speculative replicas of the visible gears to increasingly data-driven reconstructions that integrate X-ray tomography, deciphered inscriptions, and simulations of its lost components. These advances have transformed simple functional models into complex 3D reconstructions that demonstrate the device's ability to track planetary motions and predict eclipses,

fundamentally reshaping our understanding of its significance.[20] At the same time, these evolving reconstructions illustrate how the perception of a cultural object can shift according to both interpretative hypotheses and the rendering techniques employed. Without recording the accompanying paradata, such as the assumptions underlying the restoration of missing parts, and the technical metadata of a visualisation, future researchers may struggle to distinguish between what derives from physical evidence and what stems from technological affordances.

CONCLUSIONS

Archaeological 3D models are usually deliverables of research projects investigating archaeological remains through virtual representation, notwithstanding their associated context. Many people are currently working on the preservation of these complex digital objects from different professional perspectives, but there does not seem to be a unified structure that is drawing together all the numerous threads around preserving archaeological virtual reconstructions.

This research article shows that when considering a virtual reconstruction project, the scientific authenticity should be ensured through the preservation of the various contextual relationships (social, cultural and historical) between the final research outputs and their accompanying digital documentation (metadata/paradata). Every creative decision needs to be recorded as they change the original data into interpretation. This allows the designated communities, e.g., the archaeological, historical and digital preservation communities, to appraise the available information. A preserved archaeological virtual reconstruction, with this data attached may be more valuable as an example of ‘historical knowledge’ rather than as an example of archaeological evidence.

NOTES

[1] Nestor C. Tsirliganis et al., “New Ways in Digitization and Visualization of Cultural Objects” (Conference paper, International Conference on Digital Signal Processing, Santorini, Greece, July 1–3, 2002), https://ieeexplore.ieee.org/document/1027921.

[2] Julian D. Richards, Kieron Niven and Stuart Jeffrey, “Preserving Our Digital Heritage: Information Systems for Data Management and Preservation,” in *Visual Heritage in the Digital Age*, ed. Eugene Ch’ng, Vincent Gaffney and Henry Chapman (London: Springer, 2013), 318.

[3] Massimo Cultraro, Francesco Gabellone and Giuseppe Scardozzi, “Integrated Methodologies and Technologies for the Reconstructive Study of Dur-Sharrukin (Iraq)” (Conference paper, AntiCIPAting the Future of the Cultural Past, Athens, Greece, October 1–6, 2007). https://www.isprs.org/proceedings/XXXVI/5-C53/papers/FP050.pdf.

[4] Paul Reilly, “Data visualization in archaeology,” *IBM Systems Journal* 28, no. 4 (1989): 569–579, doi: 10.1147/sj.284.0569; Seamus Ross and Mary Feeney, “Information Technology in Humanities Scholarship: British Achievements, Prospects, and Barriers” (Report 6097, London, 1993).

[5] Janet Delve, Hugh Denard and William Kilbride, “Digital Preservation Strategies for Visualisations and Simulations” (Conference paper, Preservation of Complex Objects Symposium: Visualisations and Simulations, Portsmouth, UK, June 16–17, 2011), https://www.cdpa.co.uk/POCOS/books/pocos_vol_1.pdf.

[6] Duncan H. Brown, *Archaeological Archives: A guide to best practice in creation, compilation, transfer, and curation* (Archaeological Archives Forum, 2011), 9.

[7] David Koller, Bernard Frischer and Greg Humphreys, “Research Challenges for Digital Archives of 3D Cultural Heritage Models,” *Journal on Computing and Cultural Heritage* 2, no. 3, 2009: 1–17, doi: 10.1145/1658346.1658347.

[8] Richard Beacham, Hugh Denard and Franco Niccolucci, “An Introduction to the London Charter” (Conference paper, CIPA/VAST/EG/EuroMed Joint Event: The E-volution of ICTechnology in Cultural Heritage, Nicosia, Cyprus, October 30–November 4, 2006, https://londoncharter.org/introduction.html.

[9] Thomas Strothotte, Maic Masuch and Tobias Isenberg, “Visualizing Knowledge about Virtual Reconstructions of Ancient Architecture,” (Conference paper, Computer Graphics International Conference, Canmore, Canada, June 07–11, 1999. https://ieeexplore.ieee.org/document/777901.

[10] Daniele Ferdani et al., “3D Reconstruction and Validation of Historical Background for Immersive VR Applications and Games: The Case Study of the Forum of Augustus in Rome,” *Journal of Cultural Heritage* 43 (2020): 129–143, doi: 10.1016/j.culher.2019.12.004; Tom Frankland and Graeme Earl, “Authority and Authenticity in Future Archaeological Visualisation” (Conference paper, Making Visible the Invisible: Art, Design and Science in Data Visualisation, Huddersfield, UK, March 10–11, 2011). https://eprints.hud.ac.uk/id/eprint/12775.

[11] Victor M. Lopez-Menchero and Alfredo Grande, “The Principles of the Seville Charter,” in Proceedings of the 23rd CIPA Symposium, (CIPA Heritage Documentation, 2011), 5.

[12] Hugh Denard, “A New Introduction to the London Charter,” in *Paradata and Transparency in Virtual Heritage*, ed. Anna Bentkowska-Kafel and Hugh Denard (London: Taylor & Francis, 2016). 57.

[13] Jenny Mitcham, “Preservation of Digital Objects at the Archaeology Data Service” (Conference paper, Preservation of Complex Objects Symposium: Visualisations and Simulations, Portsmouth, UK, June 16–17, 2011), https://www.cdpa.co.uk/POCOS/books/pocos_vol_1.pdf.

[14] David Anderson et al., “Final document analyzing and summarizing metadata standards and issues across Europe” (Report D3.3, 2010), 17.

[15] Brian Lavoie and Richard Gartner, “Preservation Metadata (2nd edition)” (Report 13-03, Great Britain, May 2013), 2, https://doi.org/10.7207/twr13-03.

[16] Andrew Wilson, “Significant Properties of Digital Objects,” Workshop, Joint Information Systems Committee, the British Library and Digital Preservation Coalition, London, UK, April 7, 2008.

[17] Guillaume Boutard, Catherine Guastavino and James Turner, “A Digital Archives Framework for the Preservation of Artistic Works with Technological Components,” *International Journal of Digital Curation* 8, no. 1, 2013: 42–65, doi: 10.2218/ijdc.v8i1.237.

[18] Esther Rodríguez González, Josep R. Casals and Sebastián Celestino Pérez, “Application of real-time rendering technology to archaeological heritage virtual reconstruction: the example of Casas del Turuñuelo (Guareña, Badajoz, Spain),” *Virtual Archaeology Review* 14, no. 28, 2023: 38–53, doi: 10.4995/var.2023.17460.

[19] Tony Freeth et al., “A Model of the Cosmos in the ancient Greek Antikythera Mechanism,” *Scientific Reports* 11, 2021: 1–15, doi: 10.1038/s41598-021-84310-w.

[20] Sudipta Samadder, “Current Research on the Antikythera Mechanism,” in *Decoding the Antikythera Mechanism: Mystery of the Ancient World*, ed. Kanish Baskaran (Edmonton: Golden Meteorite Press, 2021), 69.

BIBLIOGRAPHY

Anderson David, Delve Janet, Pinchbeck Dan, Konstantelos Leo, Lange Andreas and Bergmeyer Winfried. “Final document analyzing and summarizing metadata standards and issues across Europe.” Report D3.3, 2010.

Beacham Richard, Denard Hugh and Niccolucci Franco. “An Introduction to the London Charter.” Paper presented at 2006 CIPA/VAST/EG/EuroMed Joint Event: The E-volution of ICTechnology in Cultural Heritage, Nicosia, Cyprus, October–November 2006. https://londoncharter.org/introduction.html.

Boutard Guillaume, Guastavino Catherine and Turner James. “A Digital Archives Framework for the Preservation of Artistic Works with Technological Components.” *International Journal of Digital Curation* 8, no. 1, 2013: 42–65, doi: 10.2218/ijdc.v8i1.237.

Brown Duncan H. *Archaeological Archives: A guide to best practice in creation, compilation, transfer, and curation.* Archaeological Archives Forum, 2011.

Cultraro Massimo, Gabellone Francesco and Scardozzi Giuseppe. “Integrated Methodologies and Technologies for the Reconstructive Study of Dur-Sharrukin (Iraq).” Paper presented at 2007 International CIPA Symposium: AntiCIPAting the Future of the Cultural Past, Athens, Greece, October 2007. https://www.isprs.org/proceedings/XXXVI/5-C53/papers/FP050.pdf.

Delve Janet, Denard Hugh and Kilbride William. “Digital Preservation Strategies for Visualisations and Simulations.” Paper presented at 2011 Preservation of Complex Objects Symposium: Visualisations and Simulations, Portsmouth, UK, June 2011. https://www.cdpa.co.uk/POCOS/books/pocos_vol_1.pdf.

Denard Hugh. “A New Introduction to the London Charter.” In *Paradata and Transparency in Virtual Heritage*, edited by Anna Bentkowska-Kafel and Hugh Denard, 57-72. London: Taylor & Francis, 2016.

Ferdani Daniele, Fanini Bruno, Piccioli Maria Claudia, Carboni Fabiana and Vigliarolo Paolo. “3D Reconstruction and Validation of Historical Background for Immersive VR Applications and Games: The Case Study of the Forum of Augustus in Rome.” *Journal of Cultural Heritage* 43, 2020: 129–143, doi: 10.1016/j.culher.2019.12.004.

Frankland Tom and Earl Graeme. “Authority and Authenticity in Future Archaeological Visualisation.” Paper presented at 2011 ADS-VIS: Making Visible the Invisible: Art, Design and Science in Data Visualisation, Huddersfield, UK, March 2011. https://eprints.hud.ac.uk/id/eprint/12775.

Freeth Tony, Higgon David, Dacanalis Aris, MacDonald Lindsay, Georgakopoulou Myrto and Wojcik Adam. “A Model of the Cosmos in the ancient Greek Antikythera Mechanism.” *Scientific Reports* 11, 2021: 1–15, doi: 10.1038/s41598-021-84310-w.

Koller David, Frischer Bernard and Humphreys Greg. “Research Challenges for Digital Archives of 3D Cultural Heritage Models.” *Journal on Computing and Cultural Heritage* 2, no. 3, 2009: 1–17, doi: 10.1145/1658346.1658347.

Lavoie Brian and Gartner Richard. “Preservation Metadata (2nd edition).” Report 13-03, Great Britain, May 2013. https://doi.org/10.7207/twr13-03.

Lopez-Menchero Victor M. and Grande Alfredo. “The Principles of the Seville Charter.” In Proceedings of the 23rd CIPA Symposium, 1-5, CIPA Heritage Documentation, 2011.

Mitcham Jenny. “Preservation of Digital Objects at the Archaeology Data Service.” Paper presented at 2011 Preservation of Complex Objects Symposium: Visualisations and Simulations, Portsmouth, UK, June 2011. https://www.cdpa.co.uk/POCOS/books/pocos_vol_1.pdf.

Reilly Paul. “Data visualization in archaeology.” *IBM Systems Journal* 28, no. 4, 1989: 569–579, doi: 10.1147/sj.284.0569.

Richards Julian D., Niven Kieron and Jeffrey Stuart. “Preserving Our Digital Heritage: Information Systems for Data Management and Preservation.” In *Visual Heritage in the Digital Age*, edited by Eugene Ch’ng, Vincent Gaffney and Henry Chapman, 311-326, London: Springer, 2013.

Rodríguez González Esther, Casals Josep R. and Celestino Pérez Sebastián. “Application of real-time rendering technology to archaeological heritage virtual reconstruction: the example of Casas del Turuñuelo (Guareña, Badajoz, Spain).” *Virtual Archaeology Review* 14, no. 28, 2023: 38–53, doi: 10.4995/var.2023.17460.

Ross Seamus and Feeney Mary. “Information Technology in Humanities Scholarship: British Achievements, Prospects, and Barriers.” Report 6097, London, 1993.

Samadder Sudipta. “Current Research on the Antikythera Mechanism.” In *Decoding the Antikythera Mechanism: Mystery of the Ancient World*, edited by Kanish Baskaran, 66-76, Edmonton: Golden Meteorite Press, 2021.

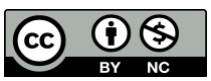
Strothotte Thomas, Masuch Maic and Isenberg Tobias. “Visualizing Knowledge about Virtual Reconstructions of Ancient Architecture.” Paper presented at 1999 Computer Graphics International Conference, Canmore, Canada, June 1999. https://ieeexplore.ieee.org/document/777901.

Tsirliganis Nestor, Pavlidis George, Koutsoudis Anestis, Politou Eugenia, Tsompanopoulos Apostolos, Stavroglou Konstantinos and Chamzas Christodoulos. “New Ways in Digitization and Visualization of Cultural Objects.” Paper presented at 2002 International Conference on Digital Signal Processing, Santorini, Greece, July 2002. https://ieeexplore.ieee.org/document/1027921.

Wilson Andrew. “Significant Properties of Digital Objects.” Workshop. Joint Information Systems Committee, the British Library and Digital Preservation Coalition, London, UK, April 7, 2008.

SOCB PROCEEDINGS SERIES 01.1

School of Collectively Building
International Conference on **Sustainable Inside and Outside**
12-14 May, Vienna, Austria 2025



www.schoolofcollectivelybuilding.com