Proceedings in Technology Transfer

Djihed Berkouk · Uday Chatterjee · Tallal Abdelkarim Bouzir · Imed Ben Dhaou · Samar Altarteer *Editors*

Proceedings of the 2nd International Conference on Creativity, Technology, and Sustainability

CCTS 2025, 30 April–1 May, Jeddah, Saudi Arabia

CCTS 2025
2nd INT. CONFERENCE ON CREATIVITY, TECHNOLOGY AND SUSTAINABILITY

OPEN ACCESS

Proceedings in Technology Transfer

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ISSN 2948-2321 ISSN 2948-233X (electronic)
Proceedings in Technology Transfer
ISBN 978-981-95-7606-7 ISBN 978-981-95-7607-4 (eBook)
https://doi.org/10.1007/978-981-95-7607-4

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Preface

This book presents the selected proceedings of the Second International Conference on Creativity, Technology, and Sustainability (CCTS 2025), held at Dar Al-Hekma University in Jeddah, Saudi Arabia, from April 30 to May 1, 2025. As a multidisciplinary academic forum, the CCTS 2025 conference explores the synergies between creative innovation, cutting-edge technology and sustainability strategies. This second edition builds on the success of the first and highlights the growing importance of collaborative research, deeply connected to today's sustainable development challenges, as defined by the United Nations' Sustainable Development Goals (SDGs) and the Kingdom of Saudi Arabia's Vision 2030.

The conference received 130 full paper submissions from researchers representing 25 countries and 76 institutions worldwide. Each submission underwent a rigorous peer-review process, evaluated by at least two independent experts. Following this meticulous review, 53 papers were accepted for inclusion in these proceedings, ensuring both academic rigor and a diverse exploration of the conference themes.

The various chapters contained in this book offer case studies, theoretical frameworks and scientific contributions that provide a comprehensive overview of how technology, stimulated by creativity, can be effectively mobilized to address multidimensional sustainability challenges. These contributions span a broad spectrum of relevant topics, carefully organized into three distinct parts:

- Harnessing Technology for a Sustainable World: This section highlights how technological advancements can serve as powerful tools for sustainability. It features contributions on AI-driven design and planning, sustainable housing and urban development, data science for environmental monitoring, advancements in sustainable materials and construction, as well as broader reflections on the role of technology in addressing global sustainability challenges.
- Diverse Applications of Technology and Creative Solutions: The second section showcases the wide-ranging impact of technology across various sectors. This section features applications of AI and machine learning, the role of technology in education and well-being, the intersection of human factors and technology, advancements in environmental and industrial technology, and considerations for information systems and future trends.
- Shaping a Sustainable Future: The Role of Creativity in Societal and Economic Transformation: The final section focuses on the crucial role of innovation and strategic thinking in achieving sustainability. This part addresses economic policy and its impact on sustainability, the power of creativity and innovation for sustainable solutions, the application of technology for sector-specific sustainability, the integration of sustainability into business strategy, the importance of security and automation for sustainability, and an analysis of emerging trends.

Throughout this book, the contributions show how important it is to use creativity and technology together to deal with the challenges of sustainable development. The research and ideas shared aim to increase awareness, support the use of sustainable practices, and encourage cooperation between researchers, professionals, and decision-makers. Each part of the book connects to key global sustainability priorities. Part I addresses SDG 9 and SDG 11, focusing on sustainable infrastructure, innovation, and urban development. Part II connects to SDG 4, SDG 3, and SDG 8, emphasizing quality education, public health, and inclusive economic growth enabled by technology. Part III reflects SDG 12, SDG 13, and SDG 17, highlighting responsible innovation, climate action, and the importance of global cooperation. Together, these chapters provide useful insights and practical steps, offering a clear roadmap for progress toward a more sustainable, equitable, and technology-driven future.

We extend our deepest gratitude to the leadership of Dar Al-Hekma University, particularly the President, Dr. Abeer Aldoghaither, and the Vice President of Graduate Studies, Research and Business Division Dr. Norah Farooqi, for their unwavering support and visionary guidance. We are equally grateful to the authors for their valuable contributions and dedication to advancing knowledge in these critical fields. We are profoundly indebted to the international panel of reviewers and Program Committee members for their rigorous, constructive, and timely evaluations. Our sincere appreciation goes to the dedicated conference organizers whose meticulous efforts ensured the event's success. We are especially grateful to Dar Al-Hekma University for providing an exceptional, collaborative environment as host institution, fostering the rich exchange of ideas central to CCTS 2025.

It is our firm hope that the innovative ideas, research findings, and practical solutions within this volume will inspire further interdisciplinary collaboration, spark creative partnerships, and catalyze impactful actions towards building a more sustainable, equitable, and technologically empowered future.

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A Climate-Aided Methodological Approach for Regenerating Cultural Heritage in Fragile Landscape

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Abstract. The notion of building construction, survival, and destruction undeniably intersects with intricate climatic, political, social, and economic agendas. From ancient Mesopotamian cities until the end of time, buildings have not only been generators of meanings and stories but they have also been encapsulating these stories. Therefore, the destruction of architecture, along with being a very unsustainable practice, fuels the loss of the collective spatial memory of an urban settlement and empties it of meanings related to identity and belonging. The paper focuses on the importance of architectural preservation and rehabilitation practice of modernist buildings that emerged from 1920s-1940s during the colonial era of Beirut, Lebanon. Moreover, it discusses how classifications of what constitutes culturally significant sites can aid the process of memory capsulation of such edifices, by using a case study approach of the St. George Hotel & Bay, the first reinforced concrete modern building in Beirut city. The paper will discuss not only the interlinked relationship between modernist heritage rehabilitation and Climate-aided Design (CADe) but also how data-driven environmental design strategies can mitigate and adapt to climate change risks by utilizing advanced digital prototyping tools and regenerative design principles to enhance anti-fragile and resilient actions in Mediterranean coastal cities like Beirut.

Keywords: Urban Regeneration · Climate-aided Design · Cultural Heritage

1 Introduction

Demolishing buildings and cities, especially after crisis scenarios, can pave the way for a better future or erase certain traumatic stories. However, it is also the easiest and most effective way to obliterate the collective memory and the physical identity of the built environment. At the same time, building construction and operation is responsible for around 40 to 50% of the total energy consumption worldwide. According to the Intergovernmental Panel on Climate Change (IPCC) in their fourth Assessment Report (AR4), the increase in the atmospheric concentration of carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) happened during the last two centuries because of human activities exceeding any precedent pre-industrial numbers [1].

D. Berkouk et al. (Eds.): CCTS 2024, PTT, pp. 66–74, 2026.
https://10.1007/978-981-95-7607-4_8

The paradigm of how to approach and conceptualize an urban intervention has been the central focus of architects, designers, and urbanists throughout the centuries. These explorations often investigate the potential for building a better future, regardless of the level of uncertainty of this future. But what if the notion of building, as in the sense of construction, becomes at the expense of destroying more buildings, especially ones that express historical and symbolic significance? According to the United Nations (UN), around 68% of the world's population will live in cities and urban areas by 2050 [2]. At the same time, new land use is becoming more disruptive to natural habitats and ecosystems, and in a future where more urbanization will be trendier, the destruction of culturally notable structures is becoming more evident. This presses the urge to reconsider not only the climatic and social challenges facing the practice of building in cities today but also to prompt mitigation and adaptation strategies to what seems to be an unavoidable climatic catastrophe.

The IPCC report concludes with the urgency to encourage integrated design solutions for buildings, which is employing both passive and active techniques in monitoring and optimizing thermal comfort, ventilation, light distribution, and visual comfort to reduce energy requirements [3]. This raises an important statement of how environmental design can be utilized as a survival tool in urban settlements for a more sustainable future, and how classification, preservation, and adaptive reuse of existing cumulative heritage buildings can be a catalyst for urban regeneration processes.

The focus of the study draws into Beirut city, Lebanon, a coastal city on the east of the Mediterranean basin, known historically for its urban complexity and diverse cultural identity. Also, Beirut is part of the Eastern Mediterranean and the Middle East (EMME) climatic zone [4], which is considered a climate change hotspot as it is highly vulnerable to shifts in both extreme and average climate conditions. This is because the EMME region is warming up twice as fast as the global average and the implications of this climatic change are already evident today in the form of intensified droughts, heatwaves, and other extreme weather events [5].

Beirut is a city with a rich and layered history, stretching back to the fifteenth century BCE. Over time, it evolved from a Phoenician port into a Roman colony, a medieval village, an Ottoman city, and later a French protectorate. The city's transformation began during the late 19th century, under Ottoman rule, with a development boom that marked the start of continuous urban change. After World War I and the fall of the Ottoman Empire, Lebanon became part of the French Mandate in 1920. This sparked the first major wave of destruction in the city, as Ottoman-era buildings were replaced by a Western "Parisian" style of urban planning in what is now known as the "Haussmannization of Beirut". More waves of destruction happened since the independence, the Lebanese civil war (1975–1990), after the war of 2006 and 2024, leaving the city in a constant state of destruction and rebuilding [6].

The chosen case is the first modern building in Beirut that has used reinforced concrete for its construction. Designed and built in 1929 during the French mandate by the Parisian architect Auguste Perret and Lebanese architect Antoine Tabet. Located on the waterfront in Beirut's downtown core, it was claimed during the 1960s as one of the best seven hotels globally. However, since the civil war, it has struggled with any form of utility and was threatened multiple times with demolition because it is not listed as

part of Beirut's cultural heritage from the colonial era that is noteworthy to be saved [7]. With every wave of destruction, Beirut is subject to becoming more climatically fragile to extreme weather as well as it loses part of its cultural identity, especially the downtown of the city. Then with every wave of reconstruction, political and economic private stakes were prioritized over anti-fragile and constructive measures [8].

Therefore, the paper aims to explore how significant landmarks like the St. George Hotel, which embodies part of the city's colonial, post-independence, and post-civil war spatial memory, can become catalysts for regenerating urban landscapes. Also, to highlight the potential of Climate-Aided Design (CADe) to assist early design stages. The hypothesis is that utilizing CADe as a main driver to preserve and rehabilitate underutilized structures can be an approach to reduce the environmental impact of high carbon footprint, potential waste of energy, material resources, and maintenance by leveraging the embodied energy of the existing setting. Moreover, enhances the site's climatic performance and resilience to future environmental threats which could ultimately contribute to its preservation. The aim is to create a framework that integrates environmental de-sign practices from digital prototyping, multi-scalar environmental analysis, future scenario forecasts, and CADe to aid preservation efforts of French colonial architecture experiments during (1920–1940) in cities of the Levant, exemplified by the St. George Hotel in Beirut.

2 Methodology

The methodology embraced for this case included, first a deep historical and theoretical review that sets a foundation for allocating the significance of St. George Hotel to the spatial narrative of a city like Beirut. Second, a multi-scalar risk assessment of the current state-of-art condition and future scenario forecast of Beirut's downtown area. This multi-scalar approach (see Fig. 1) from an urban scale to the building scale would represent the site's relationship with its context and identify multi-risk factors of both the building and the downtown area. The relationship between the St. George Hotel and the downtown area was primarily studied through the writings of Lebanese historians and architectural theorists, who laid down a critical narration of the interaction between national identity conservation and the practices of destruction and expansion of the city's colonial and post-colonial periods. These include Robert Saliba, an urban historian and a Professor of urban history at the American University of Beirut, who tackled the conservation practices of colonial heritage in Beirut's central and pericentral districts since independence. Saree Makdisi, a Professor of comparative literature and colonial studies at UCLA, discussed the post-civil war aftermath of Beirut's downtown. Assem Salaam [9], a renowned Lebanese Architect and academic, criticized post-war reconstruction plans carried out during the 1990's.

On the other hand, the methodology to analyse and forecast current and future environmental and urban risks to downtown Beirut and the St. George Hotel embodied an integrated workflow starting from digital documentation from GIS data primarily obtained by Beirut Urban Lab [10], which is a collaborative, interdisciplinary research lab organised by the American University of Beirut. In addition, a collection of GIS and historical image sources like the Google Earth Engine, Arab Centre Archives (ACA) and

site inspections between 2019 and 2022 was used. All maps, plans, sections, images, and Geo-referenced 3D models, obtained from open street maps, helped the digital prototyping process using Rhinoceros 3D.

Regarding current climate conditions and environmental analysis, a few key performance indicators (KPIs) were considered regarding urban and building scale levels. A complementary effort between the Autodesk Forma platform, Climate Studio plugin, and Grasshopper Ladybug plugin was utilized. Forma provided a powerful insight into running heavy urban scale simulations including sun hour analysis, wind speed and flow, comfort study, and microclimate analysis that combines thermal, wind, and shade information to visualize areas of optimal comfort within the urban context taking into account buildings orientation and shadow cast by the surrounding context. Climate Studio was useful at a site area and building-scale level where higher resolution of details is preferred to simulate primarily incident radiation analysis of the facades and roofs and the ground plane. In addition, it is effective to show an accurate perception of indoor space, direct and indirect daylight availability, direct and indirect solar radiation and glare study. Regarding the future scenario forecast, certain KPIs needed to be taken into consideration to foresee and visualize the symptoms of climate change on urban and building scale levels respectively.

This includes risks like temperature rise, the effect of the urban heat island effect (UHI), and sea level rise throughout 5, 25, and 50-year intervals. So, EPW (EnergyPlus Weather) forecast weather files, site-specific to Beirut were obtained using Meteonorm 8.0, including air temperature, relative humidity, global solar radiation, wind speed and direction, etc. This was done following Representative Concentration Pathway (RCP) 4.5 for moderate emissions scenario for 2030, 2050 and 2080. The obtained data was then plugged into a grasshopper ladybug tool to eventually visualize and compare the results of incident radiation. Ladybug enables you to view thorough climate data through interactive graphs and spatial mapping, as well as import climate files in EPW format.

Concurrently, forecast climatic data of Lebanon concerning thermal comfort, number of hot days, rise of sea level, etc. were collected from several sources, including the World Climate Research Program, the Coastal Risk Screening Tool developed by Climate Central, and Lebanon's climate fact report published by the Lebanese Red cross. These were analyzed in comparison to psychrometric charts of the key years generated by Climate Studio. Finally, sea level rise was simulated and visualized using Grasshopper Kangaroo plugin based on the data gathered from Climate Central and the Lebanese Red Cross.

3 Result

Urban landscapes in politically and economically hazardous regions like Beirut face extreme challenges to mitigate and adapt to future climate change scenarios compounded by the long-lasting struggle with the lack of adequate infrastructure, poverty, high population density, and conflicts. Eventually, they are also burdened with future scenarios of an environmental crisis. Therefore, traditional evaluation and intervention approaches must consider context, including infrastructure adequacy, socio-economic conditions, and local methods and materials.

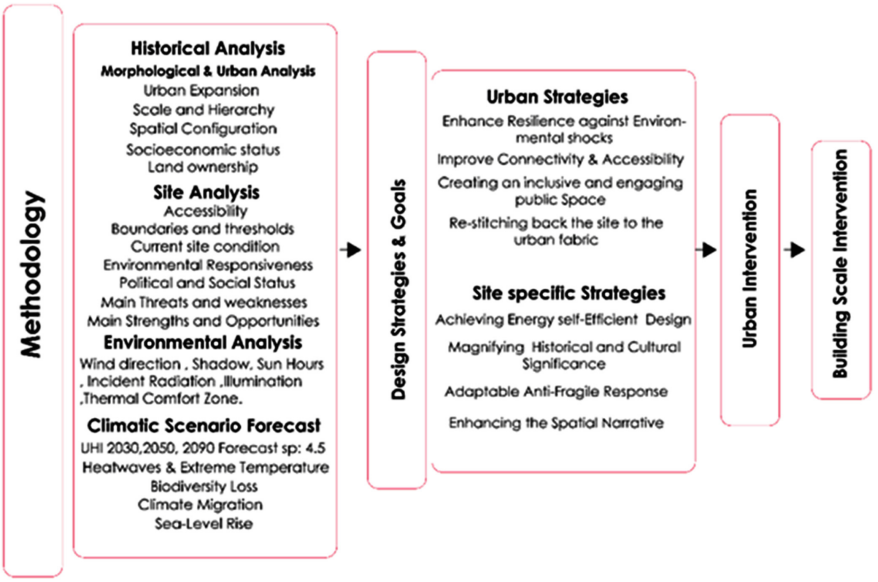

Fig. 1. Methodological Approach

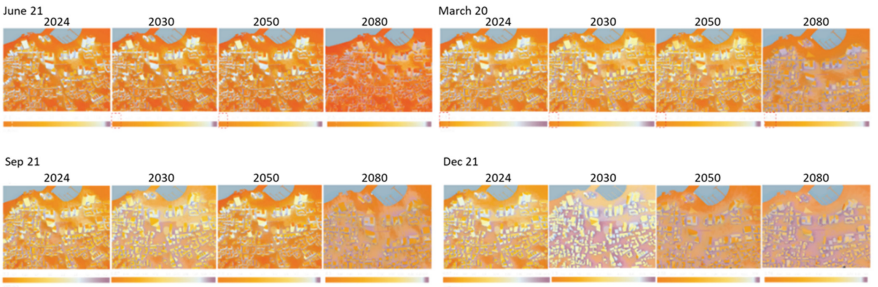

Fig. 2. Radiation Analysis and forecast of Beirut's CBD area 2024,2030,2050,2080 from left to right respectively. Top left June 21. Top right September 21. Bottom left March 20. Bottom right December 21

Since the civil-war ended (1990) The Saint George Hotel stood at the edge of Beirut's empty down. The empty promises of prosperity following the war have transformed the Central Business District (CBD) into a ghost town, alienating its connection to everyday Lebanese life. This is because 80% of buildings in the downtown have been either damaged beyond repair or demolished, two-thirds of which have been wiped out in the name of reconstruction and modernity. The area has been reserved for multi-millionaire real estate developments and seasonal tourism, pushing the majority of Beirut's residents away from its centre. The sign "STOP SOLIDERE" is a striking reminder of the ongoing battle to preserve Beirut's identity. The hotel embodies the struggle to protect the city's history from erasure, serving as a memory incubator in a city that has lost significant parts

of its spatial narrative. This deeply rooted legacy raises an immediate need to visualize the future of the St. George Bay and Hotel.

From an environmental perspective, Beirut lacks adequate blue and green infrastructure, endures increasingly extreme summer hot waves, and has already experienced an annual mean temperature increase of 0.3 °C per decade since 1970, which is twice the global average. This phenomenon is forecasted to worsen even more decade after decade. This can be seen from the predictions provided by World Climate Change Program reports on Lebanon and the radiation forecast analysis carried out for the key years. Each period (2030, 2050, 2090) shows a steady increase in solar radiation levels across the entire urban landscape of the downtown, contributing to a worsening UHI effect (see Fig. 2). June 21 exhibits the highest incident radiation, with values rising to 7.5 kWh/m^2 by 2090, compared to 7.1 kWh/m^2 today. Moreover, the number of very hot days (>35 °C) will reach 11–21 days annually by 2050 and more than 25 days by 2090. Under RCP 4.5, the moderate scenario applied, mean temperature will rise by 3.1 °C, intensifying heat stress in the city.

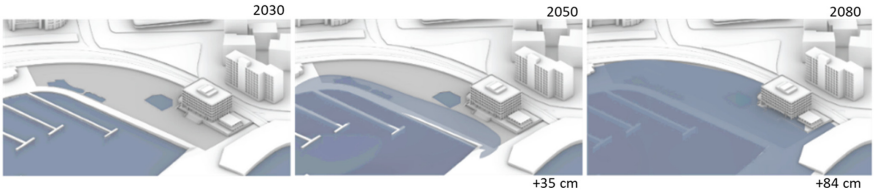

Fig. 3. Sea level rise simulation for 2030 (left), 2050 (middle), 2080 (right)

The psychrometric chart forecast analysis demonstrates an overall shift towards warmer conditions and higher humidity levels by 2090 (with ratios above 0.025 kg water/kg air). This by default decreases the number of hours that fall within both indoor and outdoor thermal comfort zones, causing more probability of extreme heat and making it harder to maintain comfort using passive strategies. According to the Lebanese Red Cross, it is projected that by 2050, the sea level in the coastal cities of Lebanon, where 90% of the population lives, will be 30–60 cm higher. Using this rate, 20 mm per year, it is expected that by 2100 sea level will rise 80–100 cm (see Fig. 3). This would not only increase the risk of coastal flooding but also cause saltwater intrusion into coastal aquifers. Concerning the site, since its construction the building morphed from a two-storey structure to triple in size to 6 storeys today.

This happened due to several reasons ranging from economic boom and expansion to war battles and conflict that have resulted in a series of restoration and reconstructions. As a result, the climatic performance of buildings was highly affected by fast and unstudied restorations. The original structure used to embed passive shading and cooling features to reach thermal comfort like wind towers, a central atrium, overhanging balconies, breeze walls etc. that were highly contextual and responsive to the climate at the time. Many of these aspects were lost and the building today finds itself again struggling to perform optimally.

4 Design Solution

The intervention aimed to represent a balanced relationship between memory preservation and addressing the pressing need to mitigate and adapt against upcoming climatic risks. This is conveyed by revitalizing the connection between the waterfront, the city, and the site as a continuously activated public space stitching it back to the city's fabric. This was done while simultaneously incorporating measures to mitigate the Urban Heat Island (UHI) effect, reaching net energy efficiency, safeguarding against sea level rise, and enhancing indoor and outdoor thermal comfort.

As a result, actions on the site involved considering Nature-Based Solutions (NBS) to transform the under-utilized outdoor area into a floodable public space that features rain gardens and water pools carefully zoned in high-radiation zones to enhance evaporative cooling. Native, drought-tolerant, and endangered plant species like Juniperus Drupacea, Quercus Calliprinos, Thymus Libanotius, Crataegus Azarolus, Cyclamen Libanoticum, Alkanna Maleolens Bornm, were deployed to reduce water consumption, combat biodiversity loss, and create shade. Also, the building's basement was re-purposed as an extension of the urban park, blurring the harsh definition between public versus private areas. This aspect is apparent throughout most of the project to achieve a better relationship between the building and its surroundings.

Moreover, at the building scale, the intervention broadens the concept of the public space by visualizing multifunctional layers stacked vertically, combining environmental performance with public accessibility. The design prioritizes two main goals: first, referring back to the original design's passive cooling strategies. Second, pulling out learnings from the local vernacular architecture, in terms of materiality, organization, and climatic responsiveness. Therefore, one of the main actions was to allow sunlight to penetrate the basement to create a chimney effect that ensures passive natural ventilation throughout the structure. This approach allows sufficient wind circulation from the basement to the roof, promoting indoor air quality and thermal comfort. A pool positioned in the basement helps in cooling hot air during the summer, thereby maximizing the building's environmental resilience. By integrating these decisions, the design combines public and private functions, optimizing usability while enhancing a sustainable and climate-responsive architectural solution.

5 Discussion

The study on the St. George Hotel employed both qualitative and quantitative methods to investigate the complementary relationship between a theoretical framework and applied research. The proposal examined a detailed assessment of Beirut's vulnerability to climate change and its potential of such under-recognized sites to be a catalyst of urban regeneration processes rather than silently wait for its dismissal.

Today, the urgency to save St. George as it is one of the few colonial heritage buildings that stand today is undeniable. Nevertheless, why does it remain unrecognized for conservation and who benefits from the current state of constant erasure of heritage combined with an urban governance framework? Moreover, While the results stress the necessity to support adaptive design intervention using advanced modeling techniques

and CADe on fragile landscapes to combat future risks scenarios and aid the preservation process, it may still be a niche approach for various reasons. For instance, the economic and political atmosphere combined with the lack of the institutional agenda may be a barrier to application.

While this approach provides an essential perspective to apply CADe and assist the evolution in the field of climate risk assessment in rehabilitation practices, it is essential to acknowledge restrictions such as the reliance on limited climate models and emission scenarios that may include some inaccuracies. For instance, although climate models and projections offer valuable insight into site-specific conditions, they may not consider all microclimatic conditions. Also, the limitation of the modelling approach using multiple data sources to create close approximations. In addition, in a rapidly changing urban setting, further alterations of context structures, evolution, orientation, heights and materiality may affect the building's performance and responsiveness to adapt to future threats.

6 Conclusion

The case of the St. George Hotel re-examines the essence of what creates continuous multi-layered cities in the first place, which is the adaptability and resilience of its layers to survive the test of time, natural disasters, conflicts, and man-made destruction. The main goal of this experiment was to showcase the potential of mandating and recognizing Beirut's modernist legacy as part of the collective heritage of the city. It is time to adopt climate-resilient preservation practices as part of Lebanon's heritage conservation policy. Also, the proposal points to a framework to stimulate anti-fragile generative measures in fragile landscapes applied to other coastal cities of the Mediterranean and encourage urban policies that embrace CADe as a tool for urban regeneration practices.

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D. Berkouk et al. (Eds.): CCTS 2024, PTT, pp. 487–489, 2026.
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