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Climate Design: Holistic Solution for Climate Resilience

Veerabhadran RAMANATHAN[1,2,3], Peter HEAD[4], Elfatih ELTAHIR[5,6], Glen T. DAIGGER[6,7,8], Cynthia E. SMITH[9], Makoto YOKOHARI[10], Peter CHILDS[4,11], Jun MA[8,12], Kongjian YU[3,13,*]

1 Scripps Institution of Oceanography, University of California San Diego, San Diego, CA 92093, USA
2 National Academy of Sciences, Washington, D.C. 20418, USA
3 American Academy of Arts and Sciences, Cambridge, MA 02138, USA
4 Royal Academy of Engineering, London SW1Y 5DG, UK
5 Center for Global Change Science, Massachusetts Institute of Technology, Cambridge, MA 02139, USA
6 National Academy of Engineering, Washington, D.C. 20001, USA
7 Civil & Environmental Engineering, University of Michigan, Ann Arbor, MI 48109, USA
8 Chinese Academy of Engineering, Beijing 100088, China
9 Cooper Hewitt, Smithsonian Design Museum, New York, NY 10128, USA
10 ARISE City Research Unit, The University of Tokyo, Tokyo 113-8654, Japan
11 Dyson School of Design Engineering, Imperial College London, London SW7 2AZ, UK
12 School of Environment, Harbin institute of Technology, Harbin 150000, China
13 College of Architecture and Landscape, Peking University, Beijing 100080, China

*CORRESPONDING AUTHOR
Address: Rm. 501, Peking University Science Park, 127-1 Zhongguancun North Street, Haidian District, Beijing 100080, China
Email: kjyu@urban.pku.edu.cn

ABSTRACT

The 2024 Climate Design Summit, held on October 29, 2024, emphasized the importance of interdisciplinary approaches in tackling climate change challenges. Experts from architecture, engineering, and environmental science gathered to discuss sustainable solutions for mitigating climate disasters like floods, wildfires, and droughts. The summit advocated for cross-disciplinary solutions that integrate Nature-based Solutions as catalysts for climate resilience and are essential for long-term sustainability, and stressed that no single technical solution can address the complexity of climate issues. Successful case studies were highlighted as examples of how design can address both climate resilience and socio-economic challenges. The gathered insights and discussions on this summit reinforced that achieving climate resilience requires a holistic approach that blends scientific innovation, sustainable design, and community empowerment, and underlined the need for collaboration across disciplines and sectors to build resilient cities and infrastructures.

KEYWORDS

Climate Resilience; Interdisciplinary Design; Nature-based Solutions; Sustainable Infrastructure; Urban Regeneration

HIGHLIGHTS

- Interdisciplinary collaboration is vital for addressing complex climate challenges
- Nature-based Solutions are key to promoting climate resilience and sustainability
- Holistic approaches integrate design, science, and community for resilient cities and infrastructures

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Introduction

The 2024 Climate Design Summit was held on October 29, 2024 in Peking University. It brought together global experts in climate change and design innovation to discuss interdisciplinary pathways to address the crises—such as floods, droughts, and wildfires—caused by climate change and their threats to human survival. The core goal of the summit was to advance climate resilience and advocate for interdisciplinary, cross-scale solutions, encompassing collaboration across fields from civil and environmental engineering to architectural design, with a focus on promoting green transformation and sustainable development. Attendees unanimously agreed that, in the face of climate crises, single technical solutions are insufficient, and only through the integration of multiple Nature-based Solutions and collaborative efforts can a true ecological civilization be achieved.

Climate Change Status Quo: An Urgent Call for Action

Veerabhadran RAMANATHAN

The climate crisis is no longer a distant threat but a pressing reality, affecting at least two billion people worldwide through extreme weather events. In addressing this challenge, it is essential to not only focus on survival but also on thriving amid these changes. Sustainable living strategies must become a global priority, and climate design plays a pivotal role in mitigating the impact of this crisis.

For over fifty years, scientists have studied the Earth's atmosphere, with significant contributions coming from satellite and drone technology. Satellites designed in collaboration with NASA have provided valuable data on the greenhouse effect, which is a primary driver of global warming. In particular, drones were used to map pollution over the Indian Ocean, revealing how pollution contributes to heat absorption. This work has provided a clearer understanding of how carbon emissions affect long-term climate change.

Carbon dioxide (CO_2) has been identified as a major contributor to global warming. The accumulation of CO_2 creates a thickening "blanket" around the Earth, trapping heat and contributing directly to global warming. Emissions from any part of the world have the same effect, emphasizing that the climate crisis is a global issue that requires a collective response.

In the 1970s, scientists initially believed CO_2 to be the only man-made pollutant causing global warming. However, further research revealed other substances, such as chlorofluorocarbons (CFCs), also play a significant role in atmospheric heating. One ton of CFCs has the same warming effect as 10,000 tons of CO_2. In response, the international community took swift action, banning CFCs through the Montreal Protocol in 1985, preventing even more severe warming.

The prediction that CO_2-induced warming would be detectable by 2000 was confirmed by that time, and in 2001, the United Nations confirmed the undeniable warming of the planet. Since then, the term "global warming" has evolved into "climate change" and, more recently, "climate crisis," reflecting the escalating scale and urgency of the issue.

Extreme weather events, such as intense storms, floods, and droughts, are a direct consequence of global warming. The increased presence of water vapor in the atmosphere intensifies the water cycle, making weather patterns more severe. As global temperatures rise, the atmosphere's ability to hold water vapor increases, which exacerbates extreme weather events. These changes highlight the need for urgent climate action.

Despite international efforts to reduce emissions, global reliance on fossil fuels remains high, with fossil fuels accounting for 78% ~ 80% of global energy consumption. This ongoing dependence ensures that global warming will continue for at least another 10 ~ 15 years, underscoring the need for more effective solutions.

Reducing super pollutants such as black carbon, methane, and ozone is a crucial part of addressing global warming. These pollutants contribute to nearly 50% of the warming effect, and reducing them could yield significant results within a decade or so. Therefore, addressing these pollutants should be a key part of global climate strategies.

In addition to mitigating emissions, adaptation strategies are essential for managing the risks of climate change. This includes measures to protect vulnerable populations in areas prone to extreme weather, heat stress, and water insecurity. A balanced approach, incorporating both mitigation and adaptation, is necessary to build climate resilience.

The way forward lies in a global movement focused on climate resilience. This movement would bring together cities, governments, and communities to collaborate on actionable solutions.

Climate Change, Urbanism, and Infrastructure

Peter HEAD

Climate change is one of the most pressing challenges of our time, and evidently it is not merely a technical issue; it is deeply social, political, and economic in nature. To address this global crisis, we must unite governments, businesses, and other stakeholders. In particular, the United Nations' Sustainable Development Goals (SDGs) offer a framework that needs to be implemented across all regions, with special attention to the unique challenges faced by each area. In China, for example, there is a need to balance rapid economic growth with sustainable development, requiring collaboration across all sectors. Advanced technologies, such as digital twins, can support this transition and contribute to the creation of an ecological civilization, which represents the path forward.

The consequences of climate change are far-reaching, affecting the environment, economy, society, and public health. Mitigating environmental impacts is insufficient; it is also essential to address the social and economic impacts. Different regions will experience these effects in different ways, and it is crucial to respond with solutions tailored to each context. For instance, Africa faces specific challenges that necessitate locally-driven, context-specific solutions.

However, there are already examples of success that demonstrate the potential for change. In China, the decarbonization of energy is progressing rapidly. China now has more renewable energy capacity installed than the EU and the USA combined, which is a significant achievement. Similar progress is evident in the UK, where coal has been phased out and replaced by natural gas and renewables. UK has reduced the carbon content of its electricity grid by more than 70% since 1990, proving that large-scale decarbonization is not only possible but also practical. This transition does not necessarily compromise energy security; in fact, it has been achieved while maintaining a reliable energy supply.

Cities play a major role in this transformation. We can develop energy-efficient buildings, such as passive houses that generate their own energy from solar power. These buildings can even power electric vehicles, contributing to a self-sustaining energy system within urban areas. This could transform cities into microgrids that operate independently of external energy inputs, primarily relying on renewables. In China, the high-speed rail system has been another successful strategy for decarbonizing transport. By prioritizing rail over air travel, the country has significantly reduced emissions from transport.

Urban density is another crucial factor. High-density cities consume less transport energy because they rely more on public transport and fewer people own cars. This is a concept that many cities in the USA still fail to fully understand, where urban sprawl leads to increased energy consumption. In contrast, cities with higher population densities can support efficient metro systems and reduce the need for private car ownership. A notable example of this transformation is Seoul, where a highway was removed from the city center, and instead of constructing new roads, the metro system was expanded. This project revitalized the city, making it more inclusive and accessible, especially for those previously excluded from the city center.

Nature-based Solutions provide another promising approach. Green roofs, sponge cities, and urban greening can mitigate urban heat islands, improve air quality, and enhance the overall quality of life. These strategies offer co-benefits, such as reducing infrastructure costs, improving public health, and making cities more livable. In China, such approaches are already being implemented with tangible, measurable benefits.

Agroforestry is another vital practice that should be embraced. Planting trees alongside crops can enhance soil health, increase water retention, and support biodiversity. This approach also offers significant carbon sequestration benefits. In addition, solar panels installed above crops can provide shading, reduce water loss, and generate renewable energy, supporting more sustainable farming practices. In China, there are already examples of using solar panels in shrimp and fish farms, as well as to shade livestock, benefiting farmers by improving both agricultural productivity and energy supply.

Finally, sustainable development requires significant investment in infrastructure. Countries need to allocate a portion of their GDP to critical areas such as transportation, energy, water, and food systems. An integrated approach is essential—generally, by investing 1.5% of GDP in transport, 2.2% in energy transition, and 1% in water supply, flooding, and greening, regions can set themselves on the path to ecological sustainability. The investments made in cities like Singapore and Hong Kong, China, where 1% of GDP was invested annually in metro systems, demonstrated how long-term planning can transform urban infrastructure and contribute to sustainability.

We must continue to measure the impacts of these projects and share the results to highlight their global value. To tackle climate change and build a sustainable future, we must act now, with ambition, innovation, and collaboration.

Regional Impacts of Global Climate Change

Elfatih ELTAHIR

Climate change has a global impact, but its effects vary greatly across regions and local scales. The increasing concentrations of CO_2 and other greenhouse gases are the primary drivers of global warming, resulting in a rise in average global temperatures by slightly over 1°C. Although climate models can predict these global trends, they are insufficient to understand the specific impacts on local and regional scales, which are crucial for societal adaptation and policy decisions.

One of the most significant consequences of climate change is its impact on quality of life through changes in outdoor days. Outdoor days, defined as days with moderate temperatures that allow people to engage in outdoor activities, are vital for societal well-being. These days also affect outdoor workers' productivity, including those in agriculture and construction. Climate models suggest that, while outdoor days in high-latitude regions may increase due to warming, areas in the tropics will see a reduction. Specifically, parts of Southeast Asia, South America, and sub-Saharan Africa will experience fewer moderate-temperature days. These changes will have implications for recreation, tourism, and general public health, as people in warmer regions will face more extreme weather, which may limit outdoor activities and affect productivity.

The impacts of extreme heat are another critical concern. Extreme heat waves, especially those accompanied by high humidity, are becoming more common, particularly in regions such as Southwest Asia and the Persian Gulf. Humidity significantly affects the human body's ability to regulate heat through perspiration. When the wet-bulb temperature, a measure of both temperature and humidity, exceeds 35°C, the human body cannot effectively cool itself, leading to life-threatening conditions. Current projections indicate that areas such as Dubai, Doha, and other cities around the Persian Gulf will face future heat conditions where the wet-bulb temperature exceeds this critical threshold, posing serious risks to human health and survival.

In terms of agriculture, climate change's effects on food security are stark, particularly in regions like East Africa. Sorghum, a staple crop in countries like Sudan and Ethiopia, shows different responses to temperature changes based on local conditions. In Sudan, where temperatures are already high, climate change will push temperatures even further, negatively affecting crop yields. Conversely, Ethiopia, with cooler temperatures, may experience increased productivity as temperatures rise, bringing the region closer to its optimal growing conditions. This highlights the complex nature of climate change's impact on agriculture, where some regions may benefit from warming, while others will suffer.

Overall, the impact of climate change on local and regional scales cannot be fully understood by simply analyzing global temperature trends. It requires considering how temperature, precipitation, and humidity interact to affect human activities, agriculture, and overall quality of life. Regions that are already on the edge of these optimal conditions will experience the most significant impacts, whether positive or negative, depending on whether they are pushed into more extreme conditions.

Understanding and addressing these localized impacts are essential for effective adaptation strategies and mitigation policies. By focusing on phenomena that people care about, such as outdoor days, agriculture, and extreme heat, we can better inform local communities and policymakers about the real-world consequences of climate change. This approach emphasizes the need for a nuanced understanding of climate change, which incorporates local contexts and region-specific vulnerabilities.

Water and Environmental Engineering and Climate Change

Glen T. DAIGGER

The focus of the water management discussion is on building systems that integrate both centralized and decentralized components effectively. The key to creating sustainable water systems lies in understanding and combining all the relevant components into a cohesive system that addresses local needs. This includes not only surface water but also groundwater, which should receive more attention as both a water supply and storage medium. The system needs to incorporate storage capacity, as extensive water usage eventually requires careful management to prevent issues like salt buildup and contamination.

However, on a global scale, the current water management practices fail to meet the needs of many populations. Access to clean water and sanitation, often viewed as a fundamental human right, remains an unsolved problem in many parts of the world. While China has made significant progress in reducing poverty and providing modern water and sanitation systems, half of the global population still lacks access to safe drinking water, and only 20% of wastewater is treated adequately. This points to a significant gap in service delivery, particularly in sanitation, where innovative approaches such as source separation are gaining traction in regions like Africa.

Water management professionals are increasingly focusing on these challenges as an opportunity to introduce new practices. Innovation is often easier in regions where systems are not yet well-established, as there is less resistance to change. For example, managing water and wastewater separately—especially in terms of source separation—is becoming a focus of experimentation, with the potential to improve sanitation on a larger scale.

Despite these opportunities, a significant barrier to adopting new ideas and technologies in water management remains. The challenge lies in overcoming the inherent resistance to change. People are often reluctant to adopt new technologies, particularly when they are unfamiliar or introduced by external sources. This resistance stems from the perception that trying something new is risky, even though the real risk lies in maintaining outdated systems. Successful change depends on managing risk effectively and fostering environments that encourage adaptation and innovation.

Innovation in water management should not be about avoiding risk, but rather about managing it strategically. It is essential to plan for flexibility and adaptability in infrastructure. As technologies evolve, systems should be designed with the potential for future updates and adjustments. For example, wastewater treatment systems must be adaptable to new technologies and changing needs. As such, designing systems with future flexibility in mind is crucial for long-term sustainability.

When introducing new ideas, understanding the adoption process is key. The theory of diffusion of innovations outlines the process by which new technologies or practices are adopted across society, starting with innovators and early adopters before reaching the majority. It is important to focus on these early adopters, as they play a crucial role in demonstrating the viability and benefits of new systems. By carefully managing the introduction of new ideas, water management professionals can gradually shift the mindset of the broader population and foster widespread adoption.

Lastly, the goal is to transition toward resilient urban water systems that maximize the use of local resources, minimize external demands, and incorporate flexibility. Water reuse and efficiency should be prioritized, with an emphasis on integrating rainwater harvesting and wastewater treatment into urban infrastructure. This approach is particularly suited to regions like China, where rapid urbanization offers a unique opportunity to develop innovative systems for water and wastewater management. By combining these systems with urban planning initiatives like sponge cities, China has the potential to lead by example in sustainable water management, offering a model for the rest of the world to follow.

Socially Responsible Design and Climate Change

Cynthia E. SMITH

Design can play a crucial role in addressing pressing global challenges, ranging from a rapidly changing climate to social inequality. Through engaged and innovative approaches, design can be a catalyst for change, transforming communities, improving livelihoods, and contributing to sustainable futures. It can connect culture, tradition, and modernity, providing tangible solutions to real-world problems while fostering social, economic, and environmental resilience.

For example, a centuries-old Native American tribe in the USA reinterpreted housing preservation policy to reflect a more culturally appropriate response, one that values the life of their Pueblo over strict historic replication and material conservation. Families chose to re-inhabit the Pueblo that had fallen into disuse and was only being used for ceremonies. The design team developed an authentic architectural vocabulary, reintroduced earthen construction skills that provided tribal employment. It was the first Pueblo tribe in the USA to develop a comprehensive preservation plan that guided practical housing improvements according to cultural values, combining tradition with 21st-century sustainable infrastructure.[①]

Similarly, global warming has heightened the need for investing in disaster-resistant infrastructure, not simply short-term relief. In the Philippines, a non-governmental organization saw the need and called for the design of a school structure, which is often a place of refuge for residents, capable of withstanding the high winds of frequent typhoons. Using local, low-cost, and sustainable materials, the design was not only functional but also replicable in other vulnerable regions worldwide. This approach underscores the role of design in supporting longer-term climate strategies.[②]

Design can also drive urban regeneration and economic revitalization. Detroit provides an example of how design can guide a city's transition after decades of disinvestment and population decline. The city developed a 50-year strategic plan that used civic engagement and landscape as catalysts for economic, social, and environmental transformation. Vacant lands and industrial areas were repurposed into productive multi-functional landscapes, including blue and green infrastructure, which supported both environmental regeneration and community well-being. This example shows how design can transform abandoned urban spaces into sustainable assets that support a changing population.[③]

Another example of design responding to environmental challenges comes from New Orleans, where climate adaptation strategies are being researched by a design studio to repurpose aging oil and gas infrastructure found along the Gulf Coast of the USA. For instance, abandoned pipelines could be repurposed to transport water to coastal areas to support wetland restoration, demonstrating how design can turn environmental liabilities into opportunities for regeneration.[4]

In under-resourced regions, innovative low-cost designs can greatly improve access to healthcare. One notable example resulted from a medical doctor's keen observation that expensive infant incubators were abandoned because no one knew how to fix them, even as local mechanics were in abundance. The resulting design was a repairable incubator made using car parts, which aimed to reduce high infant mortality rates. This example exemplifies how systemic approaches can lead to the design of potentially game-changing practical solutions.[5]

Furthermore, design can engage entire communities in exploring alternative resilient construction. In informal settlements, such as those in São Paulo, Brazil, residents collaborated with urban designers to develop modular housing systems made from recycled materials. These self-built housing units, would be built with prefabricated elements made from discarded urban waste, offering upgraded housing options while reducing environmental impact. This proposal demonstrates how design can cultivate transitions to innovative regenerative models leading to healthier cities.[6]

Design can also contribute to overcoming challenges in resource-scarce locations. In Bangladesh, an architect collaborated with local boat builders to modify traditional flat-bottom riverboats to create a fleet of floating solar-powered schools, libraries, training centers, and health clinics. This design not only improved access to basic health and educational services but also offered a model for sustainable, adaptive infrastructure for increasingly flood-prone areas.[7]

The growing emphasis on sustainable innovation in design is embodied in work that employs renewable energy sources and low-cost technologies to improve living conditions and reduce environmental impact. In Botswana, for example, solar-powered hearing aid chargers are providing a sustainable solution to a critical problem. This is a clear example of reverse leapfrog technology, where an inspired design from a resource-constrained environment bypasses old technologies to impact the rest of the world.[8]

Design can be a transformative tool, ever evolving in response to complex challenges, from climate change to social inequities. By embracing long-term regenerative strategies, incorporating multiple voices and cultures, and respect for our inter-dependent ecosystems, a socially responsible design can help to build a more just, equitable, and resilient future.

① Owe'neh Bupingeh Preservation Project (Ohkay Owingeh, New Mexico, USA): designed by Atkin Olshin Schade Architects, with consultants from Ohkay Owingeh Advisors, elders, Pueblo students, and commissioned by Ohkay Owingeh Housing Authority.
② Millennium School Bamboo Project (Nato High School, Camarines-Sur, Philippines): designed by Eleena Jamil Architect for My Shelter Foundation, Philippines Department of Education.
③ Detroit Future City (Detroit, Michigan, USA): developed by a strategic framework team led by Toni L. Griffin, with Stoss Landscape Urbanism and Hamilton Anderson Associates, and civic engagement contributions from Detroit Collaborative Design Center, Michigan Community Resources, and Detroit residents.
④ Gulf Coast Climate Futures (New Orleans, Louisiana, USA): led by studio director Liz Camuti at School of Architecture, Tulane University.
⑤ NeoNuture Car-Parts Incubator (Cambridge, Massachusetts, USA): designed by Design that Matters (prototype) in collaboration with the Center for Integration of Medicine & Innovative Technology, based on a concept by Jonathan Rosen.
⑥ Urban Mining (Heliópolis, São Paulo, Brazil): proposed by Marc Angélil and Rainer Hehl, with Tomas Polach, Rafael Schmidt, and Julia Sulzer from Urban Design, Department of Architecture, ETH Zürich, in collaboration with Vanessa Padiá, Elisabete França, Maria Teresa Diniz, and Ligia Miranda de Oliveira from Secretariat for Housing, Municipality of São Paulo, and the Heliópolis settlement community.
⑦ Floating Community Lifeboats (Bangladesh): designed by Mohammed Rezwan of Shidhulai Swanirvar Sangstha to serve communities along the Atrai, Barnoi, Gurnoi, Nandhakuja, Gumani, and Boral Rivers.
⑧ SolarAid (Botswana): designed by Godisa Technologies.

Climate Design: Landscape Perspective

Makoto YOKOHARI

The urban heat island effect is a significant challenge for cities worldwide, particularly in densely populated areas like Tokyo. As cities expand, the loss of green spaces and the proliferation of "gray fabrics"—buildings, roads, and other impermeable surfaces—contribute to rising local temperatures. In Tokyo, a temperature increase of 3.5°C has been recorded over the past 130 years, with 0.8°C attributed to global climate change and the remaining 2.7°C resulting from the heat island effect.

One approach to mitigating this problem is the use of urban design strategies that guide cool air into the city. A wind corridor, for example, has been created near the Tokyo Imperial Palace, where the design of surrounding buildings and structures helps channel cool breezes toward urban spaces, making certain areas feel cooler than their surroundings. However, while these strategies can effectively reduce temperatures within a limited radius—roughly 150 m from green spaces—the effect is not sufficient to cool the entire city. To mitigate the heat island effect on a larger scale, significant efforts to restore or protect green spaces, such as large parks located every 300 m in urban areas, would be necessary.

However, implementing such large-scale green spaces is challenging, especially in densely built cities. Suburban areas, once rich in agricultural lands and natural vegetation, have experienced a decline in green spaces, exacerbating the heat island effect. As the city's population grew, the urban landscape shifted from predominantly agricultural land to more concrete and asphalt surfaces, further rising temperatures in these suburban areas and expanding the urban heat island.

Tokyo's history offers valuable lessons in urban green space integration. In the mid-19th century, about 40% of the land in Edo (old Tokyo) was dedicated to agricultural use. This included green patches integrated into the urban fabrics, which not only provided food but also helped regulate temperatures. Today, Tokyo maintains some of this legacy, with agricultural land still present on the city's outskirts and even within the 23 central wards. These green areas, though small, play a crucial role in temperature regulation and improving local microclimates.

While creating large public parks and green spaces in the city center remains a desirable goal, the financial limitations of local governments pose significant obstacles. Therefore, new models involving private sector participation are emerging. For example, a "green bonus" system has been implemented in certain parts of Tokyo, where real estate developers are incentivized to incorporate green spaces on their properties in exchange for additional building rights. Although these spaces are privately owned, they are made available to the public. Additionally, temporary green spaces have been created along streets, transforming ordinary thoroughfares into cool spots during the summer months.

Digital technologies are also being employed to guide people to these green spaces. For example, the Tokyo Oasis mobile application helps users navigate the city's cool spots by offering the most shaded routes, ensuring that people can avoid the harsh midday sun. By using real-time data about building locations, green spaces, and the sun's position, the application directs people to the nearest cool area, thus improving accessibility and encouraging the use of green spots during hot summer days.

Finally, making people feel "psychologically cooler" by greens is also important. Even in densely populated and crowded areas, people have historically found ways to integrate small green elements into their daily lives, such as placing potted plants or hanging flowers. While these practices may seem outdated, they reflect a traditional form of climate adaptation that still holds value today. Such practices not only contribute to cooling the environment but also improve the mental well-being of city dwellers by providing them with visual and sensory relief from the heat.

In conclusion, while large-scale green spaces are essential for reducing the urban heat island effect, it is unlikely that they can be created quickly or easily in highly urbanized cities like Tokyo. A combination of innovative public-private partnerships, digital technologies, and small-scale green interventions can help make cities more resilient to heat, while also improving the quality of life for urban residents.

Society Optioneering: Use of Morphological Analysis and Design Thinking in Exploring Options

Peter CHILDS

The concept of societal design has become increasingly significant in addressing the complexities of modern challenges across diverse disciplines. It encompasses a range of design activities aimed at shaping society through a systematic, collaborative, and interdisciplinary approach. In particular, the methodology of morphological analysis is highly useful for exploring societal options by dividing complex problems into manageable subsystems and generating diverse potential solutions.

Morphological analysis, a concept frequently applied in design, is distinct from its linguistic roots. It involves breaking down a system into its constituent components to examine the makeup of potential solutions. This approach allows designers to generate an array of options, facilitating the exploration of complex societal issues. By utilizing this technique, designers can tackle design at both micro and macro scales, ranging from nanotechnology to urban planning, thereby creating more sustainable, inclusive, and innovative solutions.

Applying this method to societal design enables a comprehensive consideration of various factors, including energy, cityscape, housing, economy, social interactions, transportation, and the environment. Each of these factors can be modeled as a subsystem, with various options available for selection within each category. For instance, one might select an energy source (such as wind or solar), combine it with a particular type of transportation (electric vehicles or trains), and align this with urban planning principles that promote sustainability and inclusivity. By synthesizing these options, designers can develop conceptual solutions that respond to the specific needs and challenges of a given society.

A key strength of morphological analysis is its ability to incorporate diverse perspectives and generate creative alternatives. Designers and policymakers can utilize this approach to explore multiple scenarios and test different configurations to determine the most effective societal solutions. This is particularly relevant when addressing complex societal issues such as climate change, energy distribution, and social equity, where many interconnected factors must be considered simultaneously.

In practice, this methodology can be augmented by computational tools to process vast amounts of data, further enhancing the efficiency and depth of the analysis. Cross-consistency analysis, for example, allows for the identification of incompatible selections within the problem space, reducing the number of potential solutions to a manageable set. By iterating through different combinations of options and refining the selections based on preferences, decision-makers can narrow down the possibilities and arrive at feasible, sustainable solutions.

Societal design is about exploring a range of options and determining the most appropriate path forward through collaborative and informed decision-making, rather than imposing a single, top-down solution. The use of methodologies like morphological analysis enables designers to engage with complex systems and develop holistic solutions that account for the diverse needs of society. By applying such systematic approaches, designers can better address the challenges of societal transformation, fostering environments that are more inclusive, sustainable, and resilient.

Thus, the use of morphological analysis in societal design offers a valuable framework for navigating complex societal challenges. Through the structured exploration of diverse options, it allows for the creation of adaptable and innovative solutions that can respond to the evolving needs of society.

Perspectives on Future Low-Carbon-Emission Urban Water System

Jun MA

Urban water systems face numerous challenges in achieving carbon neutrality, primarily due to the growing demands of urban expansion, increasing populations, and rising water and material needs. The current water supply systems, which rely heavily on the transportation and treatment of water, contribute significantly to CO_2 emissions. Wastewater treatment processes, especially in large urban areas, consume substantial energy and release significant amounts of CO_2, despite efforts to reduce emissions. Additionally, nutrients such as nitrogen and phosphorus persist in urban systems, creating pollution problems even after treatment.

Urban agglomeration complicates water supply by increasing demand and making sourcing more challenging. Water shortages often result in the diversion of water from other regions, though this is constrained by political, economic, and environmental factors. The current wastewater treatment methods, while necessary, have limitations in nutrient recovery efficiency and incur high maintenance and operation costs. Traditional approaches fail to address the complexity of nutrient cycling and waste disposal within urban systems, as nitrogen and phosphorus continue to accumulate in the environment.

To address these challenges, a shift from traditional end-pipe treatment systems to decentralized approaches that focus on resource recovery and water reuse is essential. One primary strategy for reducing emissions is improving wastewater treatment by separating waste at the source—segregating black water (from toilets), gray water (from sinks and showers), and rainwater. Separating these streams allows for more efficient recovery of nutrients like nitrogen and phosphorus, which can be repurposed as fertilizers in agriculture, reducing reliance on chemical fertilizers and minimizing urban waste.

Incorporating decentralized wastewater treatment technologies, such as advanced oxidation processes and membrane filtration, can significantly reduce CO_2 emissions and improve water reuse. These technologies enable on-site wastewater treatment, reducing the need for extensive infrastructure and minimizing transportation emissions. Advanced oxidation technologies, for instance, can enhance the degradation of organic pollutants and are especially effective in treating industrial wastewater. Moreover, integrating these processes with membrane filtration can improve water quality, making it suitable for reuse in industrial or domestic applications.

Nutrient recovery is another critical aspect of reducing emissions in urban water systems. Traditional wastewater treatment plants rely on biological processes to degrade organic matter, but these processes are energy-intensive and do not effectively recover nutrients. By viewing wastewater as a resource rather than a waste product, cities can implement systems that reclaim and recycle nutrients, particularly from black water, where most of the nitrogen and phosphorus originate. These nutrients can be converted into organic fertilizers, which enhance soil quality in rural areas, creating a circular system that benefits both urban and rural environments.

In conclusion, a shift towards a more integrated, resource-efficient approach is necessary to meet carbon neutrality goals in urban water systems. By adopting decentralized treatment systems, focusing on source separation, and using advanced technologies to recover nutrients and recycle water, urban areas can significantly reduce their carbon footprint. Additionally, converting organic waste into fertilizers for agricultural use can help balance nutrient distribution between urban and rural areas. Ultimately, a transition from traditional end-pipe treatment to a circular economy model is key to addressing the challenges of urban water management and meeting climate change and carbon neutrality goals.

Climate Design and Sponge Planet

Kongjian YU

In the face of escalating climate crises, the union of gray and green infrastructure stands as a testament to humanity's potential to reconcile with nature. Nature-based Solutions—green infrastructure in particular—embody a return to the roots of survival, aligning human ambition with the quiet, enduring processes of the land. This is not merely engineering, but a continuation of the art of survival practiced for millennia. Yet, alarmingly, only 5% of global investments channel into these living systems of resilience.

A radical shift in mindset is imperative. The cities and landscapes we inhabit must no longer be adversaries to natural forces but their kin. Gray infrastructure—floodwalls and concrete dams—stands as monuments of defiance, severing our connection to the very lifeblood of the earth. These structures accelerate water, fracture ecosystems, and erect barriers between people and the rhythms of the land. Instead, we must craft places that embrace water, hold it close, and give it the dignity of space. To slow, to retain, and to revere—this is the essence of design rooted in nature's wisdom.

The "sponge city/planet" concept materializes this philosophy[1]. A sponge city/planet does not fight the water; it dances with it. By absorbing and filtering rain, these urban and rural environments reduce floods, ease droughts, and enhance biodiversity. A recent manifestation of this principle emerges in the heart of Bangkok, where a forsaken brownfield now blooms as a sponge oasis, the Benjakitti Forest Park (Figs. 1, 2). Through modest interventions—cutting and filling land to shape islands—urban floods get remediated, the air cools, and native biodiversity flourishes. In these spaces, carbon is sequestrated even amid the densest urban forms[2].

This vision transcends isolated projects. Vast regions—the Pearl River Delta and the Yangtze River Basin in China—whisper the echoes of ancient wisdom. Rice paddies, sculpted by generations of farmers, are more than sustenance. They are living infrastructures, repositories of water, and guardians of life. Modern technology can renew these traditional systems, weaving the past into the fabric of contemporary cities.

The potential for transformation is immense. This is not an incremental step but a revolution in how we perceive our existence on this planet. Cities must cease being impermeable citadels and instead become soft and porous—extending the hand of friendship to rivers, wetlands, and forests. In this reciprocity lies the hope for a sustainable future, one where human progress mirrors the natural world's quiet persistence. The path ahead is both urgent and clear. To design for survival is not to impose but to restore. We must find the courage to listen to the land, allowing nature to dictate the rhythm and the form of our urban futures. This is the art of living—a legacy that speaks not in concrete and steel, but in the language of water, soil, and sky.


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1. Impermeable brownfield in downtown Bankbook, a tobacco factory (2019).
2. A sponge oasis delivering integrated ecosystem services and enhancing climate resilience (2022).

Conclusions

Design stands as the most holistic and transformative solution to the climate crisis—one that recognizes water as both the key and catalyst for resilience. In the unfolding narrative of global climate adaptation, it is not carbon alone that dictates survival, but the intricate dance between land, water, and life. The myopic focus on carbon reduction, driven by market-based mechanisms and engineering interventions, overlooks the fundamental force shaping our cities and ecosystems: water.

A design philosophy rooted in the principles of "sponge planet" offers a profound shift away from isolated, carbon-dominant approaches. By embracing water as the medium through which we restore balance—slowing it, retaining it, and giving it space—we unlock the potential for landscapes to heal, cities to breathe, and biodiversity to thrive. Sponge cities, inspired by the resilience of natural systems, demonstrate that flood mitigation, drought prevention, and carbon sequestration are not disparate goals but interconnected threads within a single, living design fabric.

More than one thousand projects practiced in China reveal the simplicity and power of Nature-based Solutions. These designs operate on the understanding that water, if embraced rather than expelled, can regenerate urban spaces, enhance agricultural productivity, and secure long-term ecological and social stability. It is through water-driven design solutions that we cultivate environments capable of enduring the unpredictability of climate change.

The path forward lies not in grand technological fixes or fragmented carbon schemes, but in the wisdom of landscapes shaped by water. Design must lead this revolution—one that reimagines our relationship with the earth, restoring cities and rural lands to a state of dynamic equilibrium. A sponge planet is not a distant ideal; it is a tangible, necessary reality, shaped by the hands of those who choose to design with nature, for nature, and through nature.

Competing interests | The authors declare that they have no competing interests.

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气候设计：
促进气候韧性的整体性解决方案

维拉布哈德兰·拉马纳森[1,2,3]，彼得·海德[4]，埃尔法提·埃尔塔希尔[5,6]，
格伦·T．戴格尔[6,7,8]，辛西娅·E．史密斯[9]，横张真[10]，彼得·查尔兹[4,11]，
马军[8,12]，俞孔坚[3,13,*]

1 美国加州大学圣地亚哥分校斯克里普斯海洋研究所，圣地亚哥 92093
2 美国国家科学院，华盛顿哥伦比亚特区 20418
3 美国艺术与科学院，剑桥 02138
4 英国皇家工程院，伦敦 SW1Y 5DG
5 美国麻省理工学院全球变化科学中心，剑桥 02139
6 美国国家工程院，华盛顿哥伦比亚特区 20001
7 美国密歇根大学土木与环境工程系，安娜堡 48109
8 中国工程院，北京 100088
9 美国库珀·休伊特史密森尼设计博物馆，纽约 10128
10 日本东京大学ARISE城市研究中心，东京 113-8654
11 英国帝国理工学院戴森设计工程学院，伦敦 SW7 2AZ
12 哈尔滨工业大学环境学院，哈尔滨 150000
13 北京大学建筑与景观设计学院，北京 100080

*通讯作者
地址：北京市海淀区中关村北大街127-1号北大科技园501室
邮编：100080
邮箱：kjyu@urban.pku.edu.cn

摘要

2024气候设计峰会于10月29日举办，强调了跨学科方法在应对气候变化挑战中的重要性。来自建筑学、工程学和环境科学领域的专家齐聚一堂，共同探讨减少洪水、野火和干旱等气候灾害的可持续策略。会议倡导跨领域解决方案，将基于自然的解决方案作为推动气候韧性的催化剂，并肯定了其对长期可持续性的重要作用，同时指出任何单一技术方案都难以解决复杂的气候问题。会议还展示了多个成功案例，阐释了如何通过设计提升气候韧性并应对社会经济挑战。与会专家认为，气候韧性的实现需要依靠融合了科学创新、可持续设计与社区赋权的整体性方法，且跨学科与跨行业协作在建设韧性城市和基础设施中扮演着关键角色。

关键词

气候韧性；跨学科设计；基于自然的解决方案；可持续基础设施；城市更新

文章亮点

- 跨学科协作对应对复杂的气候挑战至关重要
- 基于自然的解决方案是推动气候韧性与可持续发展的关键
- 整体性方法融合了设计、科学与社区力量，有助于打造具韧性城市与基础设施

编辑 王颖，田乐