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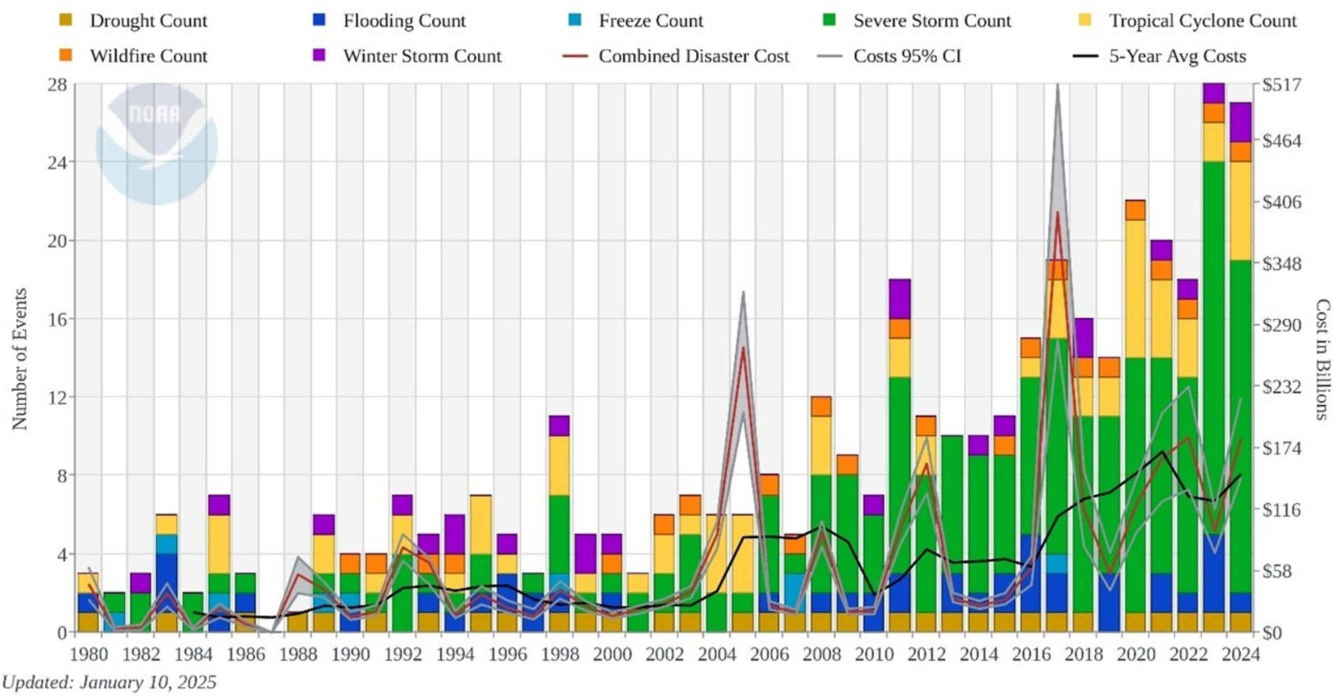
Feature May 29, 2025

Resilience by design: An economic imperative for urban development

by Raffaella Montelli and Mo Elsayed

Urban development too often unfolds as a sequence of isolated projects, each building optimized for its own site but blind to the economic interdependencies and shared risks it creates. This fragmented approach may boost short-term returns, but it sows hidden costs that erode long-term value: service redundancies, infrastructure bottlenecks, and magnified losses when disruptions occur.[1,2] This is especially true as urban areas densify, and extreme weather conditions become the new norm: billion-dollar weather and climate disasters in the United States averaged $149.3 billion per year between 2020 and 2024 (solid black line in Figure 1).[3]



From derechos in the Gulf Coast to intensifying hurricanes and shifting tornado patterns, cities are facing increased wind, water, and heat threats on multiple fronts. These forces are reshaping ecosystems and demanding a wholesale rethink of economic development and the built environment. Yet, most developments still follow ‘business as usual’, designed to yesterday’s conditions rather than tomorrow’s realities.

Municipalities are stepping up with comprehensive resilience strategies, such as the flood corridors and urban cooling programs in Houston or the extreme heat plan in Miami.[5-9] At the federal level, the National Science Foundation is supporting the development of integrated tools for assessing interconnected infrastructure risks,[10] a broad initiative that includes the University of Michigan’s study on climate-driven migration in the Lake Victoria Basin and Great Lakes region with several international partners.[11] Meanwhile, the National Academies’ Gulf Research Program is catalyzing transformative projects for a more sustainable, hazard-resilient Gulf Coast.[12] The global discourse on urban redesign—exemplified by Georgia Tech’s “Redesigning Cities”[13] series and the February 2024 Close Up[14] feature on the “15-minute city”—underscores both the promise and the retrofit challenge for U.S. metros.

These multi-scale initiatives demonstrate how coordinated planning, data-driven tools, and strategic investment can move beyond short-term fixes toward lasting economic and community resilience. Yet when development ignores its systemic impacts, the result is mounting economic drains that erode both public and private capital.[15]

Each new high-rise adds vehicles to a network already operating near capacity, turning minutes of delay into millions in lost productivity annually. Congestion cost commuters in New York City over $9 billion in lost productivity last year.[16] Disconnected land uses force utilities to overbuild or retrofit networks, driving up capital and maintenance costs by 20-50 percent compared to more compact development.[17,18] And when extreme events strike—whether windstorms, flooding, or fire—these inefficiencies translate into business interruptions, higher repair bills, insurance spikes, and taxpayer burdens, which means billions of recurring economic losses each year. Derechos alone have cost over $33 billion since 2010,[4] with record severe convective storms claims, which include derechos, exceeding $50 billion in 2024.[19]

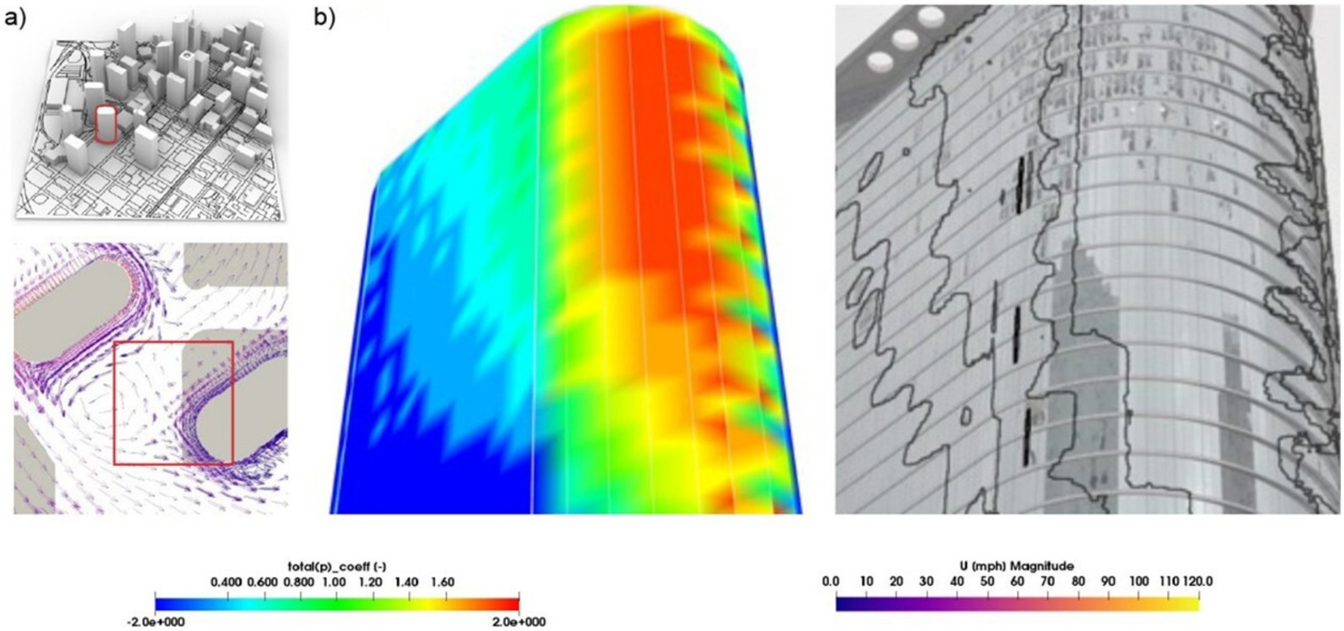
Amidst these mounting pressures and the rapid maturation of analytics, sensor networks, and simulation platforms, the stage is set for a fundamentally different approach to urban planning and development.[20,21] In this context, true resilience is not reactive; it demands foresight. At Page, resilience is viewed through an economic lens, designing from individual buildings to entire districts in ways that reduce future losses for people and assets and unlock sustained prosperity for all communities served.

Proactive resilience means systems that *absorb, adapt,* and *transform* under stress. It demands a shift from prescriptive codes based on historical norms toward performance-based approaches that simulate tomorrow’s extremes. This is more than engineering convenience; it’s a moral imperative. Every façade failure or rooftop blow-off can trigger weeks of disruptions, countless economic hardships, and in the worst cases, loss of lives and shattered livelihoods. These ripple effects accumulate over decades, ultimately impacting us all.[22,23]

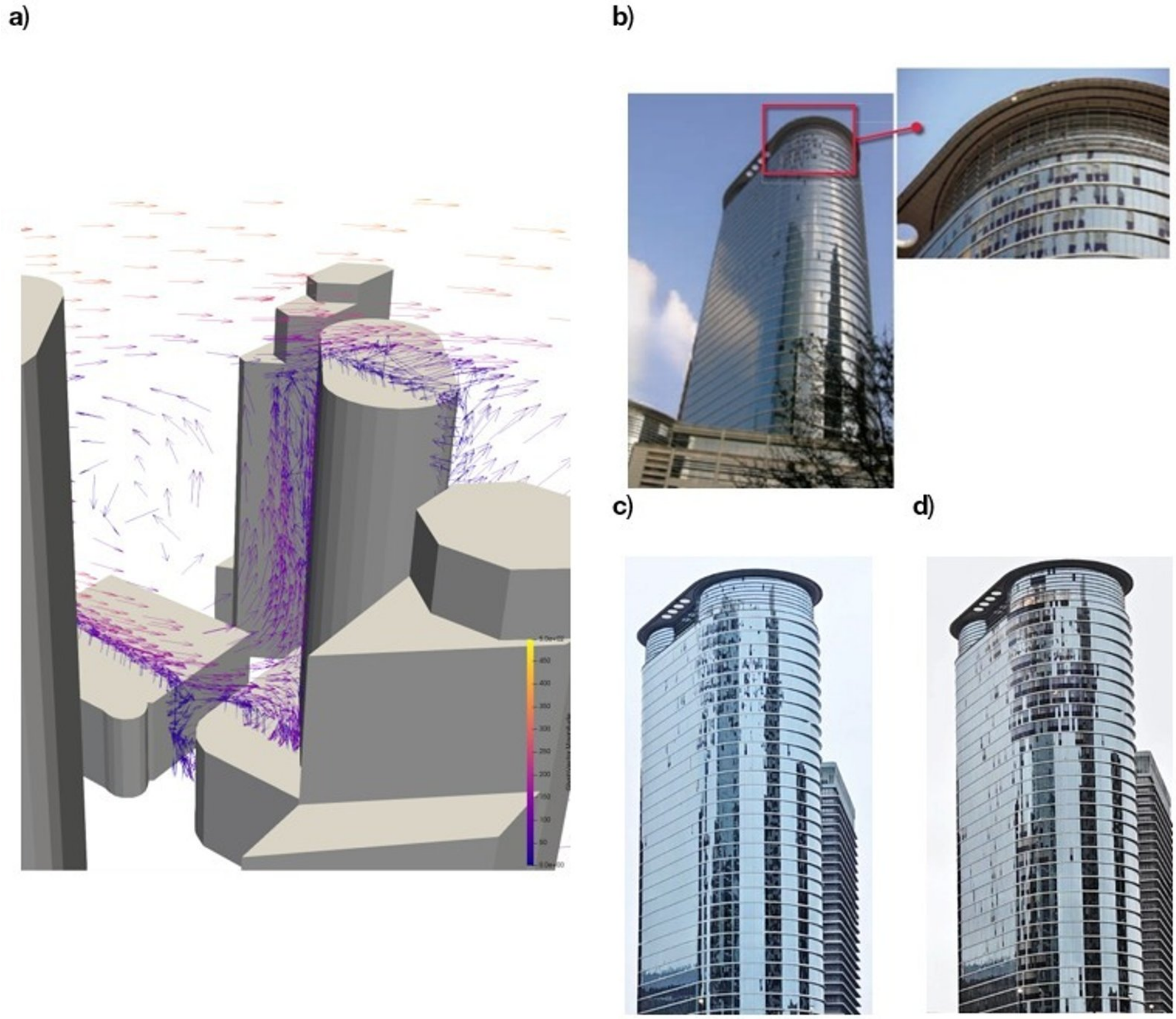
To deliver on this promise, Page deploys advanced digital modeling and physics-based simulation techniques, alone or in partnership, to simulate systemic responses of the built environment. By anchoring solutions and models in real-world data and/or calibrating them against past events and experimentation, these tools and studies help translate complexity into actionable insight, ensuring every design strengthens the urban fabric while sparking speculative, bold interventions and a broader dialogue about responsible development.

Advances in computational power and technologies, including ML/AI and data integration, are closing the gap between global atmospheric circulation models and the fine-grained realities of the built environment.[24] Computational Fluid Dynamics (CFD) has matured from a niche research tool into a cornerstone of performance-based design, including the modeling severe weather events.[25,26,27] By numerically solving the governing equations of fluid flow, CFD allows us to visualize how wind interacts with complex urban geometries, identifying suction pockets on façades, channeling effects between towers, and debris-generating vortices at street level; enabling full-city-block simulations that account for local topography, building clustering, and evolving climate inputs.

After the May 16, 2024, derecho struck downtown Houston, home to two Page offices, high-resolution 3D fluid flow simulations of the actual high-rise cluster, shown in Figure 2a, under those gust profiles generated pressure maps that precisely reproduced documented façade failures, as shown in Figure 2b.



These calculations, repeated in a different city for method validation, confirmed how dense urban “tectonics” amplify wind shear and localized turbulence, exemplified for the Chevron Global Upstream and Gas tower in Figure 3a, pinpointing the most vulnerable glazing areas to urban catalyzed vortexes, as shown in Figures 3b-d.[28,29]



The insights generated, independently corroborated by studies disseminated by the University of Houston[30, 31] and by Page's collaborators at Florida International University,[32] guide ongoing explorations of optimized infill layouts, refined setback guidelines, massing strategies, and targeted façade reinforcements with the vision of finding solutions well before the next extreme event.

As smart, adaptive cities become the new norm, resilience will go beyond static simulations and piecemeal infills. City-scale Digital Twins, where scenarios can be tested and calibrated with live sensor data, are within reach. Emerging approaches couple CFD with real-time sensor networks, creating "digital twins" that monitor wind behavior during live storms and adjust façade or damping systems on the fly. Dynamic facades that morph in response to wind conditions can significantly reduce wind loads.[33] Integrating these with machine-learning algorithms may soon allow buildings that learn and self-optimize as climates evolve. Aerodynamic retrofitting, such as adding tapered forms and recessed sections, minimizes wind-induced forces, as the Burj Khalifa and similar building forms demonstrate.[34] Advanced damping systems, like tuned mass dampers, absorb vibrational energy,[35] while strategically placed green infrastructure, including urban windbreaks, mitigate wind tunnel effects.[36] Employing high-performance materials and integrating cyber-physical systems for real-time monitoring and adjustment can further enhance structural resilience.[37] Mitigation and design considerations cannot be decoupled from the existing urban fabric, which significantly influences wind behavior during extreme events. Aerodynamic design and proper urban planning are critical in the design of future high rises to ensure the safety and resilience of urban environments, as it is for retrofitting interventions.

As urban markets evolve, resilience must be recast as an economic strategy, not just an operational safeguard. By modeling interactions, aligning incentives through partnerships, and financing shared and distributed infrastructure, long-term liabilities can be reduced, and thriving, adaptable cities can be fostered. Page's ongoing research investigations set the stage for a future where economic foresight, compounded with stronger communities, becomes the bedrock of sustainable urban development, safeguarding both assets and the communities that depend on them.

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