Council on Tall Buildings and Urban Habitat Korea

International Journal of
High-Rise Buildings
www.ctbuh-korea.org/ijhrb/index.php

International Journal of High-Rise Buildings
March 2025, Vol 14, No 1, 1-12
https://doi.org/10.21022/IJHRB.2025.14.1.1

Advanced Computational Modeling and Data Driven Design

Jeffrey A Kenoff[†] **and Luc Wilson**

Kohn Pedersen Fox Associates PC

Abstract In recent decades, advancements in computational modeling and performance simulation have transformed an architectural and urban design landscape through a focus on data-driven design. These methods unlock the ability to navigate the complexities of modern cities, such as sustainability, increased density, and programmatic transformations, by integrating form (design) with performance (data). This paper explores the role of computational modeling in creating flexible design solutions through data informed decision-making. Through recent examples of built and unbuilt KPF projects this paper will explore this paradigm shift in design processes, emphasizing the interplay between computational models and the organic complexity of contextual environments. By focusing on the integration of multi-scalar data inputs—ranging from environmental factors to specific site conditions—this paper outlines strategies for implementing performance-driven computational modeling for façade, massing, and public realm design that fosters an iterative, responsive, anticipatory approach to design, facilitating an architecture that is as much about data-driven adaptability as it is about form-making.

Keywords façade, parametric design, urban fabric, performance simulation, computational modeling, data driven design, massing design, urban design, placemaking, public realm

[†]Corresponding author:
Jeffrey A Kenoff
E-mail: jkenoff@kpf.com

1. Computational Process

1.1. From Form to Per(form)ance

Computational modeling, powered by parametric design tools such as Generative Components (introduced in the early 2000s), CATIA (adapted for architectural use in the 1990s), and Grasshopper for Rhino (released in 2007), has played a transformative role in architectural design over the past few decades. Initially, these tools were celebrated for their ability to unlock unprecedented formal freedom, enabling architects to explore and realize complex geometries that were previously unthinkable. This early period of parametric euphoria of the 1990s and early 2000s saw computational tools primarily driving formal experimentation and innovation.[1]

As the field matured, architects began leveraging these tools not only to conceive novel forms but also to address the challenges of constructability, transforming abstract designs into buildable architecture (see Figure 1). By the late 2000s, with a growing global emphasis on sustainability and the urgent need to mitigate climate change, computational tools evolved to integrate environmental data and performance metrics into the design process. Architects increasingly used these tools to set ambitious sustainability goals, simulate building performance, and optimize designs to minimize energy consumption and environmental impact.[2]

Over the last decade, this performance-driven approach has expanded in both scale and scope. Computational modeling now plays a critical role in urban design, addressing broader environmental and social challenges. Beyond optimizing individual buildings, architects use simulation tools to design public spaces that enhance outdoor thermal comfort, improve pedestrian circulation, and ensure access to quality views. This evolution reflects the profession's broader commitment to creating spaces that are not only aesthetically innovative but also environmentally and socially responsible.

1.2. Computational Design in Practice

KPF believes architectural design should be at the forefront of the transformation and evolution of computational modeling. For KPF work specifically this happens through its Design Technology groups, specifically the Computational Design, Environmental Performance, and Urban Interface teams. Over the past decade, the firm has developed and refined computational methodologies through their application on hundreds of projects worldwide. By leveraging this extensive experience, KPF has identified three primary areas where computational modeling has had the greatest impact: façade design, massing design, and public realm design.

Within each of these categories, KPF has established



Figure 1. Westlake 66: Urban Cell Wall.

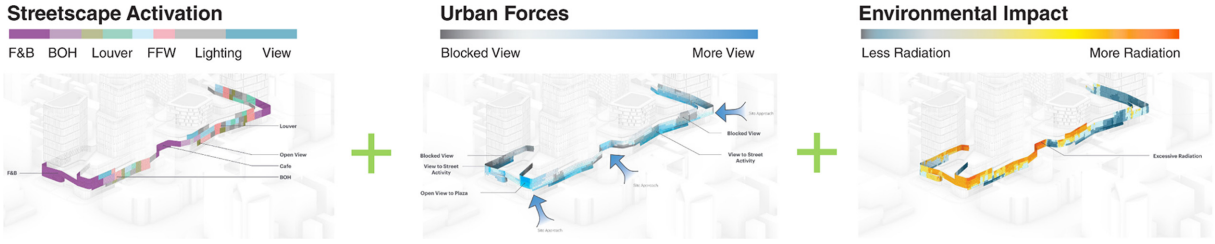


Figure 2. Westlake 66: Layers of performance analysis.

strategies for integrating performance metrics—such as optimizing views, solar radiation analysis, and outdoor thermal comfort modeling—into the design process. These methodologies allow for the synthesis of aesthetic, environmental, and functional considerations, ensuring that projects achieve both design excellence and measurable performance outcomes.

This paper examines KPF's computational approach to these three categories through a series of case studies. By analyzing these projects, we aim to codify generalizable strategies that can inform future applications of computational tools across a range of design challenges.

2. Performance, Responsiveness and Optimization

2.1. Façade Responsiveness

In the era of smart buildings and interconnected systems, architectural façades have evolved from static envelopes to dynamic interfaces that engage with complex environmental, social, and technological contexts. Advances in computational modeling and data-driven methodologies have fundamentally transformed how architects approach façade performance, empowering them to design adaptable and responsive systems. These systems address the challenges of evolving urban complexity, including ambitious environmental targets, complex uses, and the integration of design value.

2.1.1. Westlake 66 Urban Cell Wall and Towers, Hangzhou

Situated at the intersection of Hangzhou's West Lake and the Grand Canal, Westlake 66 employs computational modeling to address the challenges of a dense urban site, both through the design of performance-driven façades and in determining the location and form of the towers (as illustrated in the next section). The project is a mixed-use development that integrates a green pedestrian corridor

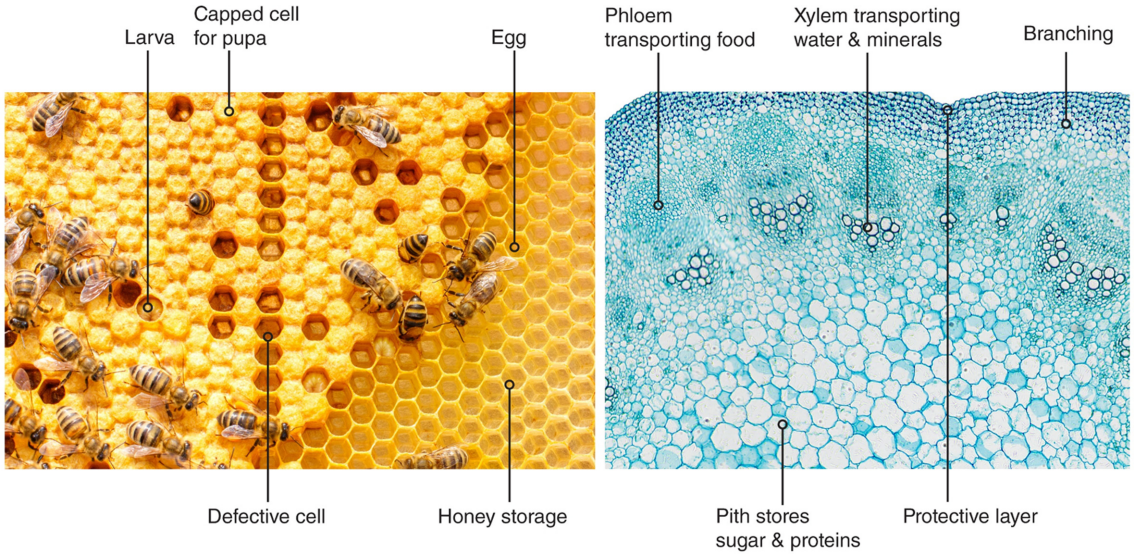


Figure 3. Urban Cellular Ecosystem biological precedents.

with a series of computationally developed terraced forms that reinterpret the relationship between architecture and landscape.

For the Westlake 66 podium, the Urban Cell Wall modules, or cells, are designed to respond to layers of programmatic use, urban visibility, and environmental impact. Humanization of materiality and scale define the multi-block wall as each cell is crafted to the height of a person and lined with a sleeve of glazed terra cotta, nodding to the city's rich ceramics heritage. The glazes of the terra cotta are inspired by the colors of the city and are modeled to slowly change tone as they wrap the city streets. As use changes and program evolves over time, the cells can be updated with new active program layers, defining a new standard for the city's urban street wall and further connecting people with place.

Given the need for the façade to perform across three complex conditions—responding to changing internal programs, maximizing urban visibility, and mitigating harmful solar radiation—each with a range of performance outcomes, the project presented the challenge of addressing over 2,800 unique conditions. Since designing and constructing that number of distinct façade panels was not feasible, the design team utilized simulation tools to quantify the performance of each condition and use the results to derive form within a computational model. This process informed the development of the Urban Cell Wall system, which was designed as a three-part interchangeable

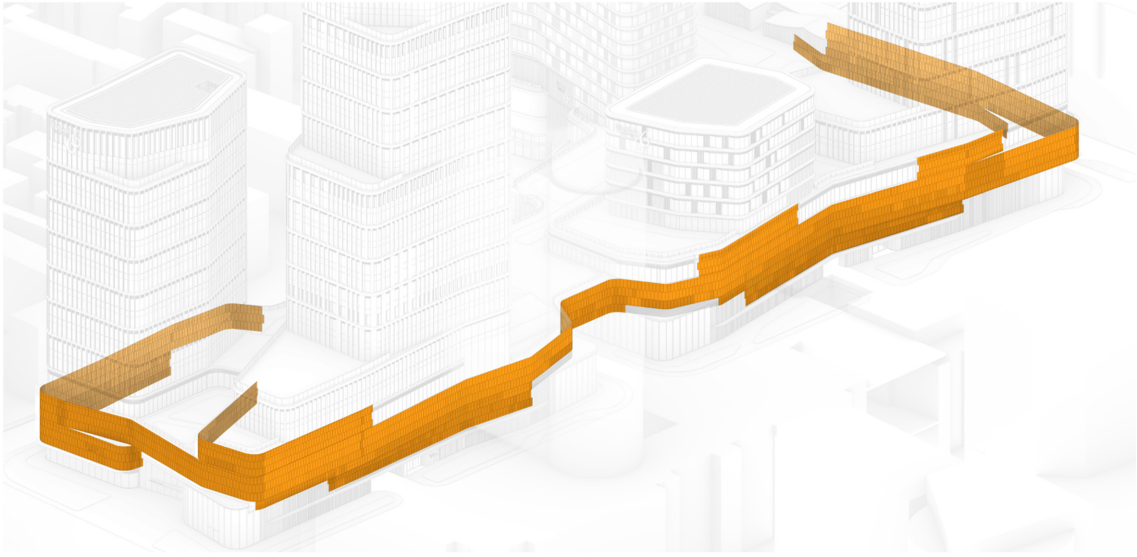


Figure 4. Westlake 66: The Urban Cell Wall.

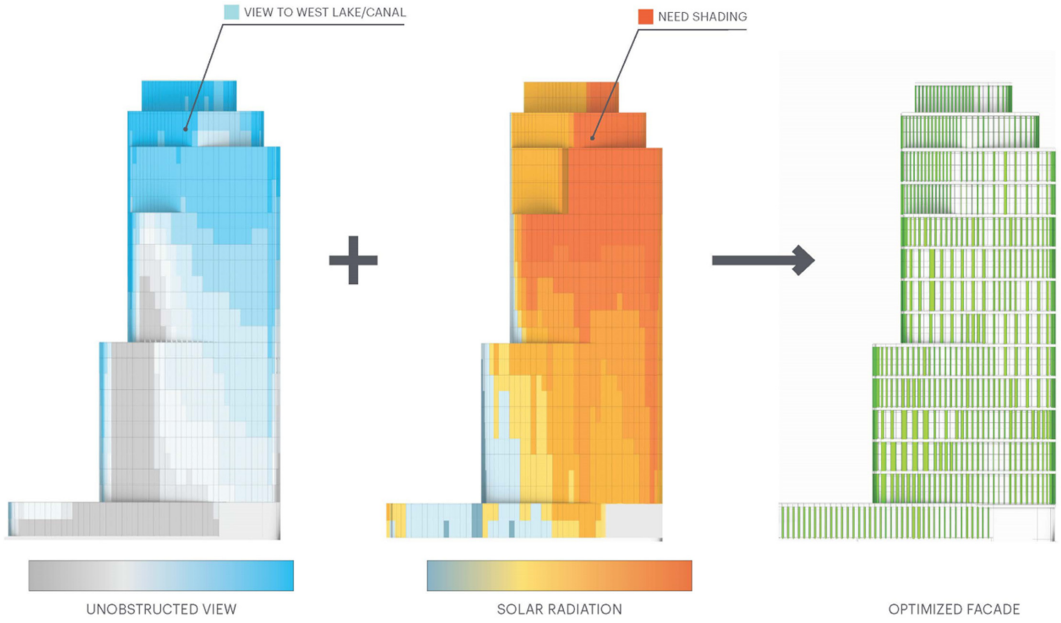


Figure 5. Westlake 66: Tower façade optimization analysis.

assembly composed of only 21 unique and substitutable components. These components were strategically assembled to meet the performance requirements of all three conditions, while simultaneously allowing for varied cell apertures to passively manage daylighting and shading, effectively reducing solar heat gain across the project.

A similar approach was applied to the design of the tower façade, where iterative simulations optimized performance for unobstructed views, solar shading, and reduced heat gain (see Figure 5). For instance, the façade geometry was carefully sculpted to maximize outward views toward West Lake while minimizing solar radiation, achieving a balance between environmental performance and occupant comfort.

This method—leveraging computational modeling to align performance analysis with flexible, modular design systems—highlights a scalable strategy for addressing complex façade performance requirements.

2.2. Data-Driven Massing Design

Performance simulation data can also play an important role in shaping the overall design of a building's massing. Designing for views and daylight is essential to enhance user experience, improve environmental performance, and maximize value. However, these objectives often present competing challenges—for instance, increasing openness to improve views can also lead to greater exposure to harmful solar radiation, resulting in glare and higher cooling loads. Leveraging computational modeling that incorporated view vectors, solar trajectories, and contextual elements, the design team was able to navigate these trade-offs, enabling the creation of building forms that are visually responsive to their surroundings, energy-efficient, and comfortable for occupants. This approach extends beyond simply optimizing for daylight and views, offering a framework that bridges aesthetics, occupant comfort, and sustainability.

2.2.1. Westlake 66 Master Plan, Hangzhou

In addition to informing façade design, computational tools were instrumental in shaping and positioning the building massings of Westlake 66. Data-driven strategies guided key design decisions for the development of the six buildings within the master plan. A computational design model was used to generate and evaluate thousands of massing options, each analyzed against performance metrics such as solar exposure, shadow impacts, internal daylighting, and visibility. This iterative process enabled the design team to balance competing priorities, including minimizing shadow impacts on surrounding contexts, maximizing daylight penetration, and ensuring optimal retail visibility at the ground level. The resulting massing strategy reflects a contextual, performance-driven approach, culminating in the creation of a porous urban composition centered on the 400-meter long Sky Park, which enhances connectivity and accessibility across the site (see Figure 6).

The core computational strategy employed in this project involved generating and analyzing thousands of massing options, using simulation data for views, daylight, and other performance metrics (see Figure 7). This iterative process allowed the design team to balance trade-offs, optimize outcomes, and create a massing solution that successfully met performance goals, while remaining sensitive to its urban context.

2.3. Public Realm Performance

As outlined in the introduction, the application of computational modeling has expanded beyond building



Figure 6. Westlake 66: The 400-meter long Sky Park.

performance to include public realm performance, placing a new emphasis on how data can inform the design of more active, walkable, and vibrant spaces. A data-driven approach to placemaking focuses on three key elements: understanding where people are likely to go (pedestrian routing analysis), what they are likely to see (visibility analysis), and how they are likely to feel (outdoor thermal comfort analysis). Unlike traditional building-focused performance metrics, these analyses prioritize the human experience, offering insights that inform decisions such as building massing, the placement of circulation elements, programmatic organization, and the design of shading and landscape features.

By leveraging these tools, architects and planners can create public spaces that are not only functional and comfortable, but also socially engaging, fostering connectivity, accessibility, and a sense of place.

2.3.1.One Vanderbilt, NY

One Vanderbilt, a 59-story office building in the heart of Midtown Manhattan, is directly connected to Grand Central Terminal, linking commuters to Metro-North, the Long Island Rail Road (LIRR), and the subway. A primary driver of the design was reducing both existing

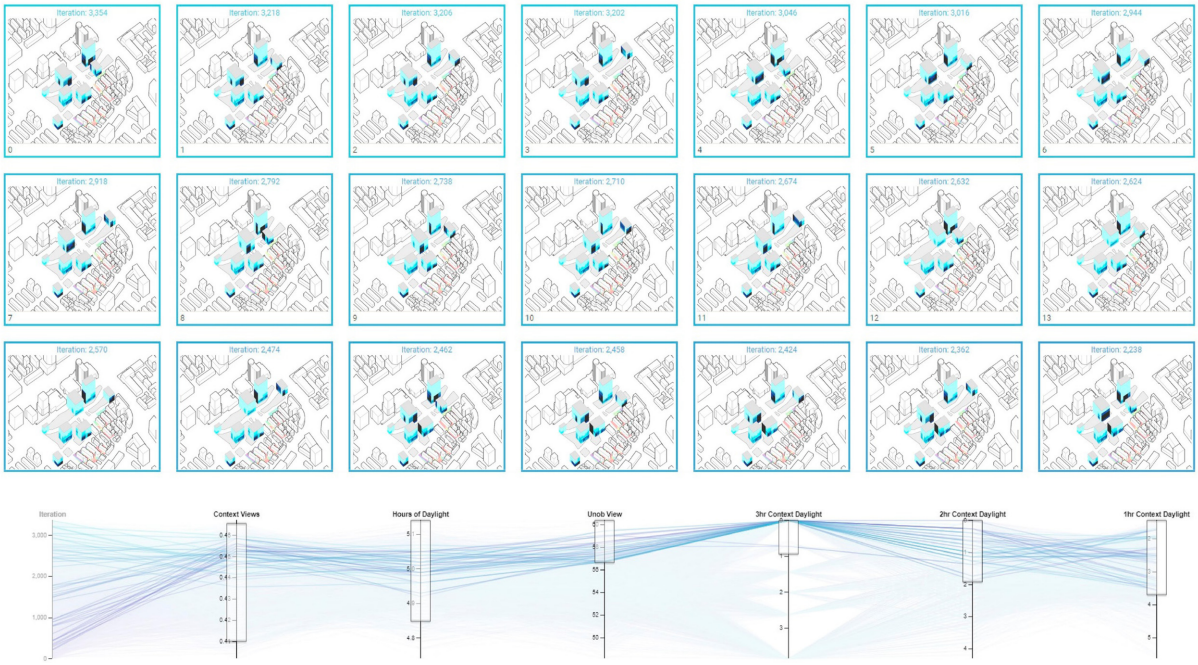


Figure 7. Westlake 66: Sample of computationally generated massing options, ranked by performance.

pedestrian congestion and the anticipated increase in foot traffic from the introduction of the LIRR connection. To address this, the design team employed advanced computational tools to simulate pedestrian routing under both current and projected conditions. These simulations informed key design decisions about how One Vanderbilt's connections to the transit system could most effectively alleviate congestion.

The process required integrating data from a neighborhood-wide Environmental Impact Statement, modeling the complex 3D pedestrian network, and applying origin/destination pedestrian modeling simulations to capture movement patterns. Based on this analysis, the design incorporated strategic interventions such as pedestrianizing Vanderbilt Avenue, setting back and angling the ground floor to expand circulation space, and widening underground connections. As a result, One Vanderbilt saves commuters an estimated 123,000 hours per year that would otherwise have been lost in pedestrian congestion.

This level of congestion reduction and optimization was only achievable through computational modeling, which enabled the design team to quantify movement patterns, anticipate future challenges, and propose targeted solutions that enhance both the commuter experience and the building's urban integration.

2.3.2. Huamu Lot 10 – The Summit, Shanghai

Huamu Lot 10 – The Summit, is conceived as an integrated nexus of culture and commerce, responding to the complexities of its urban context. This project reclaims an abandoned riverfront, transforming it into a new public space, while its three towers are connected through dramatic cantilevered sky galleries, forming a physical and visual dialogue with the adjacent museum.

Parametric analysis and environmental data were central to the building placement and cantilever positioning, ensuring the project's alignment with site forces and pedestrian comfort. By analyzing site-specific wind patterns, solar exposure, and pedestrian movement, the massing was carefully configured to optimize passive cooling and shading while enhancing the urban experience. The strategic placement of the buildings channels beneficial summer breezes through the site, improving thermal comfort in the public realm. Architectural overhangs and landscape integration further reinforce shade and cooling, creating an inviting microclimate for year-round activity. The cantilevers are defined by their reflective and hammered soffits, and are computationally positioned to maximize views and provide solar comfort along pathways of high pedestrian activity, creating a new datum that grounds the project in its urban setting.

2.3.3. T. Rowe Price Headquarters, Baltimore

The T. Rowe Price Headquarters establishes a new benchmark for sustainable design along Baltimore's harbor front, utilizing advanced parametric tools and environmental data to inform site positioning, massing, and performance. Departing from the traditional approach of compact, cost-optimized office buildings, the project embraces a design philosophy centered on community connection, environmental responsiveness, and the creation of a flexible, future-focused workplace.

Through the integration of advanced environmental analysis, the building's massing was strategically positioned



Figure 8. One Vanderbilt: The tower's ground plane.

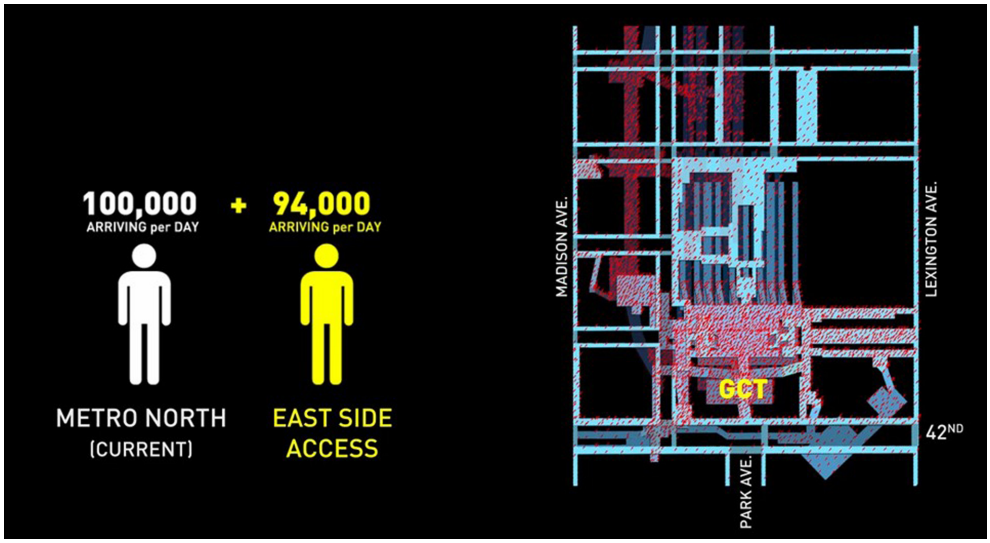


Figure 9. One Vanderbilt: Analysis of additional daily passengers.

and shaped to maximize views and enhance site-wide comfort. Parametric studies optimized massing orientation to increase daylighting strategies to minimize reliance on artificial lighting.

The project's massing also plays a critical role in enhancing occupant comfort. By carefully shaping the building to deflect harsh winter winds and channel beneficial summer breezes into the central courtyard, the design passively improves thermal comfort across the site. This effect is further amplified by a thoughtfully designed landscape, incorporating tree canopies for passive cooling and shading. Together, these elements create a pedestrian-friendly environment that advances outdoor comfort while reinforcing the project's com-mitment to sustainability.



Figure 10. Huamu Lot 10 – The Summit: Environmental performance optimized with computational modeling.



Figure 11. Building massing and cantilevers.

3. Next Generation Parametric Modeling

KPF's computational methodology has most recently evolved with the development of Track, a temporal approach to designing urban shading systems that provide year-round outdoor thermal comfort. Conceived as a response to the challenges of extreme heat and prolonged sun exposure in dense urban environments, Track also

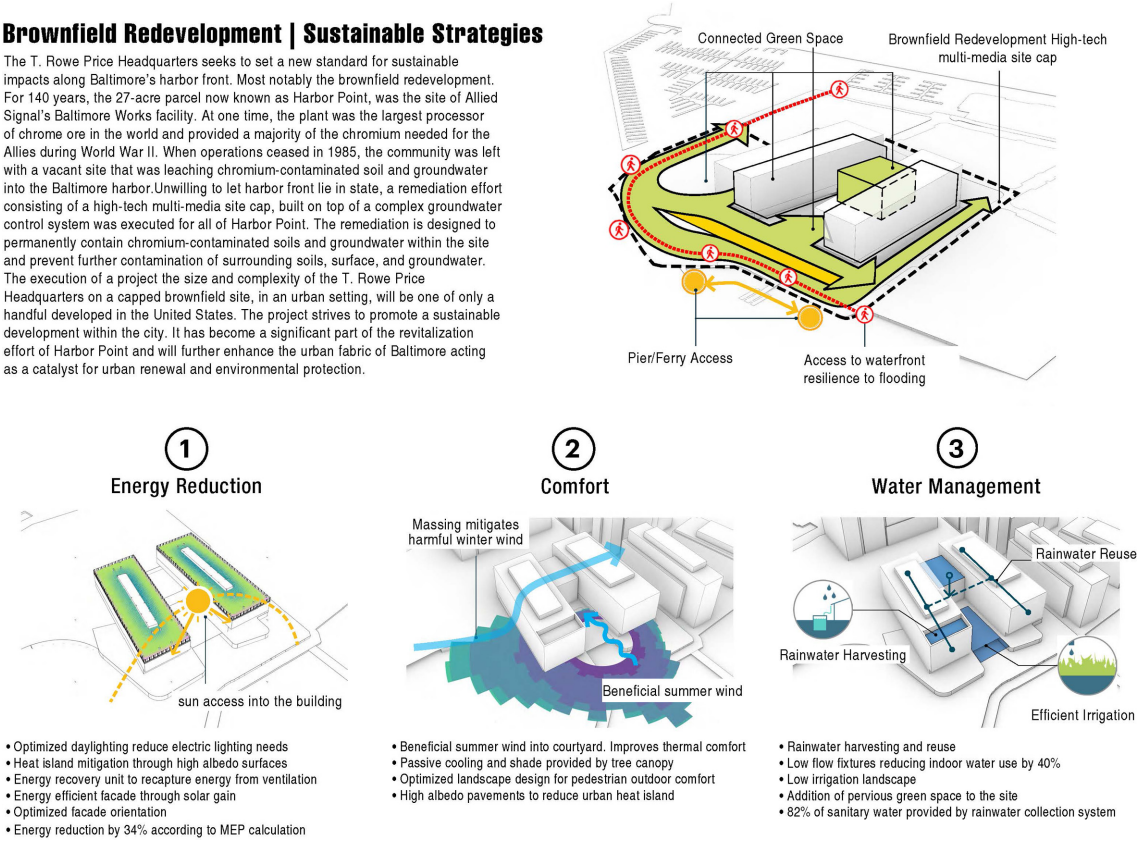


Figure 12. T. Rowe Price Headquarters: Positioning, massing, and performance analysis.



Figure 13. T. Rowe Price Headquarters: Entrance and lobby.

prioritizes the importance of exterior connectivity along active city streets. Traditional trellis systems are static, limiting their effectiveness to specific times of day or seasons, which reduces their overall environmental and experiential benefits.

To address these limitations, the design developed into



Figure 14. T. Rowe Price Headquarters: Sample of computationally generated massing options, ranked by performance.

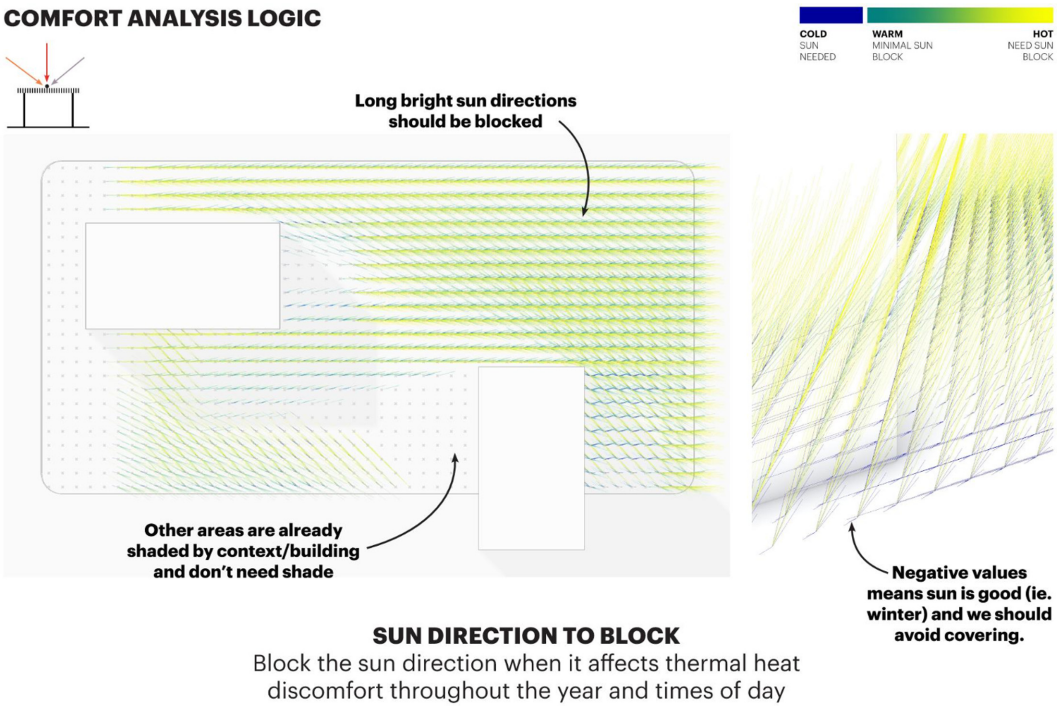


Figure 15. Track: Extraction sun angles based on thermal comfort criteria throughout the year.

a "Smart Trellis," a system capable of providing dynamic thermal comfort throughout the year while remaining stationary. By leveraging weather data—specifically sun angles and solar radiation—Track's design uses simulation tools to analyze the sun's position and intensity throughout all hours of the year and computationally determine the most effective angle of shading for each part of the trellis. Rather than physically moving to block the sun, the trellis's design strategically responds to the sun's movement, casting transient, site-specific shadows that adapt to seasonal and daily variations. The trellis ensures shaded circulation paths during hot conditions and sunlit paths during colder periods, all while allowing filtered light to create shifting, dappled patterns along its edges. This

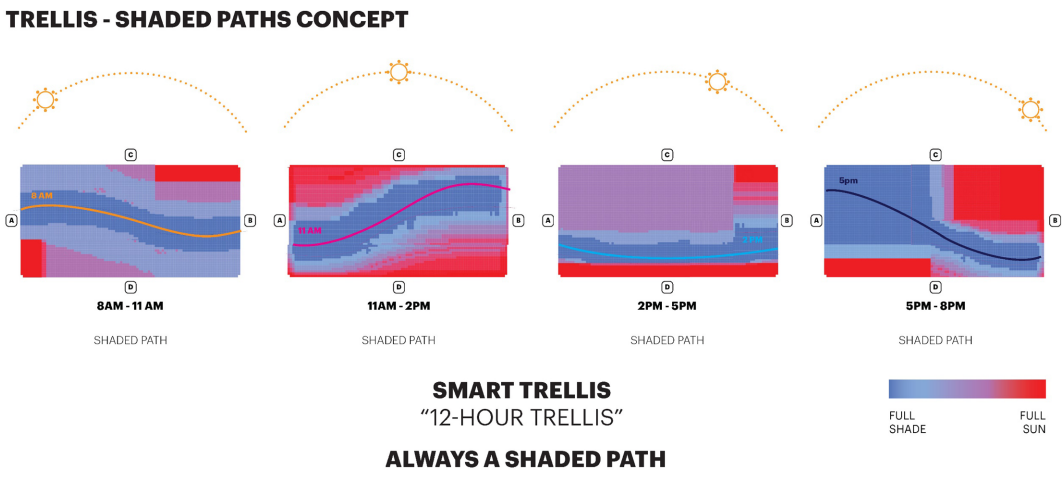


Figure 16. Track: Analysis of ideal shading conditions throughout a given day.

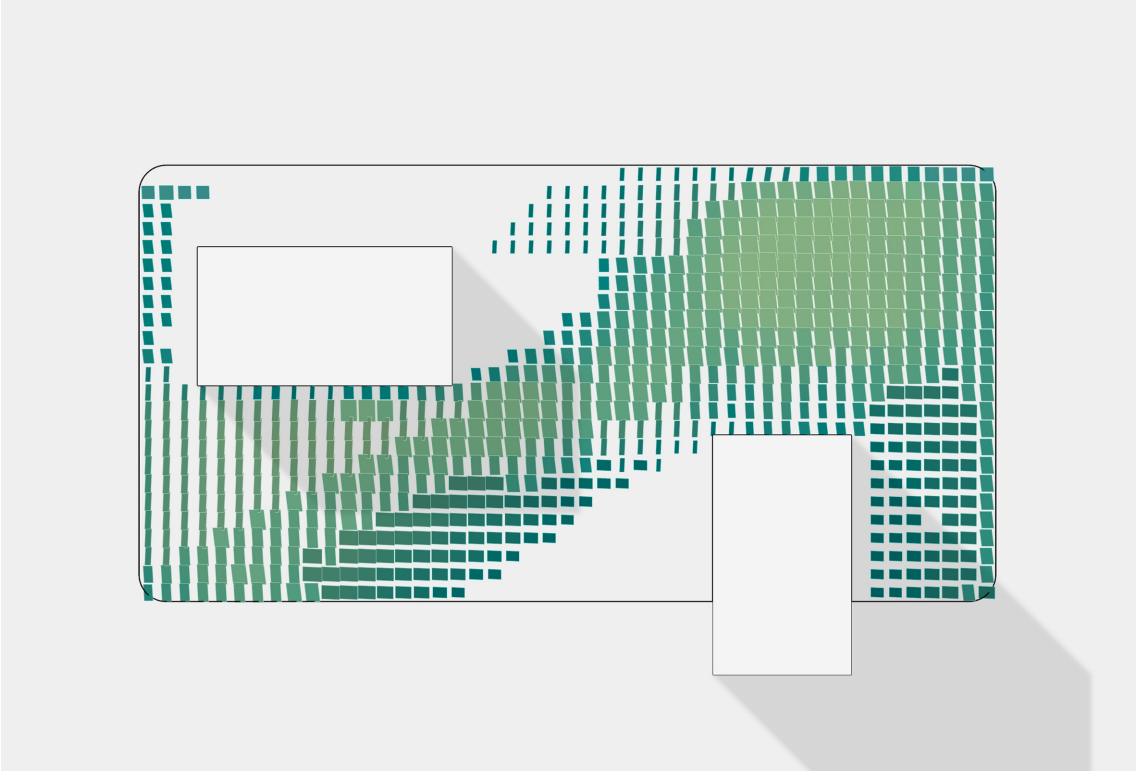


Figure 17. Track: Initial shading geometry based on thermal comfort angles.

approach not only prioritizes thermal comfort but also introduces a continuously evolving spatial experience.

This computational methodology represents the next evolution in performance-driven design, demonstrating how computational tools can craft solutions that seamlessly balance environmental sustainability, year-round usability, and experiential richness in the public realm.

4. Conclusion

This paper has explored three key applications of computational modeling—façade, massing, and public realm design—demonstrating how performance-driven strategies address complex challenges while enhancing design outcomes. Each approach leverages data to balance competing priorities, from environmental performance to user experience.

In façade design, as seen in the Urban Cell Wall system, computational tools enabled the creation of adaptable components that optimized shading, daylighting, and constructability. For massing design, projects like Westlake 66 and T. Rowe Price Headquarters used iterative

modeling to balance daylight, views, and urban context, resulting in a cohesive, high-performing master plan. In the public realm, One Vanderbilt, Huamu Lot 10 – the Summit, and "Track" showcased how pedestrian routing, visibility analysis, and temporal shading strategies can create vibrant, year-round spaces that prioritize comfort and connectivity.

These methodologies represent the current evolution of computational modeling and highlight their power to navigate complexity and deliver sustainable, human-centered solutions. As cities face unprecedented density and climate challenges, these tools enable architects to create buildings and public spaces that meet environmental goals while fostering livable, active environments.

References

Schumacher, Patrik. "Parametricism: A New Global Style for Architecture and Urban Design." *Architectural Design*, 2009.

Kolarevic, Branko, and Ali M. Malkawi. *Performative Architecture: Beyond Instrumentality*. Spon Press, 2005.