Architectural Development under the Global North-South Divide: Hybrid Strategies for Asian Megacities and AI-Enabled Tracing

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Abstract. Asian megacities sit at the sharp edge of the global North–South divide: they concentrate population and economic activity yet often lack the infrastructure capacity that comparable urban regions in the Global North take for granted. This paper synthesizes recent evidence on (i) urbanization trajectories, (ii) infrastructure inequality, (iii) urban carbon footprints, and (iv) the risk stack of congestion, heat stress, and pollution that compounds daily life in many cities of the Global South. Building on this diagnosis, we propose a hybrid architectural–urban response framework that treats "in-between" spatial thresholds, passive-to-active environmental systems, and distributed energy–water loops as scalable levers for resilient modernization in marginal contexts. Finally, we outline an AI-enabled workflow for tracing architectural works and monitoring urban transformation (from street-view and aerial imagery to heritage inventories and change detection) to support conservation, planning, and equitable upgrading. The contribution is a position-and-framework paper: it does not claim a single solution but offers a structured menu of design and governance moves that can be adapted across climate zones, settlement types, and resource constraints.

Keywords: Global north-south divide; Asian megacities; Infrastructure inequality; Hybrid architectural space; Passive design

1 Introduction: Global North-South

The concept of the "Global North–South divide" is still often used as a practical term to describe that until now there is still inequality between relatively "developed" and relatively "developing" countries or regions in terms of economic resources (wealth, access to funding, investment capacity), technological capabilities (research, industry,

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technological infrastructure), political influence (bargaining power, position in international institutions, diplomatic power). In contemporary urbanization, the divide becomes visible not only in income indicators but also in the quality and redundancy of everyday infrastructure: mobility systems, thermal comfort, air and water quality, and the ability to respond to shocks. The Global South is frequently characterized by "simultaneity" of modern and pre-modern conditions, where advanced technologies coexist with informal settlements and service deficits [2], [11]. Throughout this paper we use the Global South–North framing as a heuristic, and we align the "developing/developed" shorthand with UNCTAD's development-status groupings for country-level comparisons [14].

Hence, Asian megacities hold a significant role in this context. They function as drivers of economic expansion, destinations for population movement, and locations where environmental hazards, power consumption needs, and spatial constraints become more acute. Meanwhile, The UN forecasts indicate that Asia will continue to distribute a significant portion of the world's most populous metropolitan areas in the decades ahead [3]. The central question is therefore not whether megacities will expand, but how they can modernize under constraints that differ sharply from the assumptions embedded in many Global North planning and building standards.

This paper is a position-and-framework contribution developed from the keynote theme "Empowering the Margins, Connecting the Worlds" delivered at ARDC 2025 [1]. It proceeds in three steps: (i) a compact synthesis of evidence on infrastructure inequality and urban environmental risk, (ii) a hybrid architectural–urban response framework emphasizing "in-between" thresholds, passive-to-active systems, and distributed infrastructure, and (iii) an AI-enabled workflow proposal for tracing architectural works and monitoring urban transformation to support conservation and equitable upgrading.

2 Background: Evidence of an Urban Divide

2.1 Urbanization and the megacity trajectory

Urban growth is unevenly distributed, but its scale is most dramatic in low- and middle-income regions. The World Urbanization Prospects 2025 report highlights continued growth of large agglomerations and the increasing importance of urban regions in Asia and Africa [3]. In this context, "megacity" status is less a badge of prestige than a management condition: governance must coordinate across multiple municipalities and infrastructure operators while facing high demographic momentum.

The North–South divide intersects with this trajectory in two ways. First, cities in the Global South often reach very large populations before infrastructure networks mature (for example, before mass transit and wastewater systems reach high coverage). Second, the urbanization process frequently occurs alongside rapid internal economic restructuring, where manufacturing, services, and informal economies evolve faster than regulatory and financing mechanisms can follow [2].

2.2 Energy use, carbon footprints, and uneven responsibility

Energy use per person rises with GDP per capita, but the relationship is neither linear nor uniform; it reflects industrial structure, climate, and the availability of efficient technologies and services. Global datasets show that the high-income economies maintain high per-capita energy consumption compared to most low-income economies, even as low and mid-income cities experience rapid increases due to the changes of urban lifestyles and infrastructures [16].

At the city scale, consumption-based carbon accounting further complicates the responsibility landscape. A global analysis of 13,000 cities found that urban carbon footprints vary widely and are strongly linked to affluence and supply-chain structures, not only local emissions sources [8]. This matters for the North-South divide because "carbon space" is often claimed by high-consumption lifestyles, while climate impacts fall disproportionately on vulnerable urban residents with limited adaptive capacity.

2.3 Infrastructure gaps and the built environment

Recent remote-sensing work mapping built-up heights provides direct evidence of infrastructure inequality. Using satellite-derived 3D information, some studies show that many cities in the Global South exhibit lower and more uneven built form intensities than Global North counterparts, reflecting gaps in investment, services, and building standards [7]. These gaps manifest at multiple scales such as missing sidewalks and drainage at the street level, limited transit coverage at the district level, and systemic shortages in power and water supply reliability at the metropolitan level.

Informality is a key mediator of these patterns. The UN Habitat defines informal settlements through multiple deprivations, including inadequate access to safe water and sanitation, insecure tenure, and poor structural quality or overcrowding [11]. In architectural terms, informality is not only a housing issue; it is a "parallel infrastructure regime" where residents compensate for unreliable networks through incremental construction, local energy practices, and informal mobility.

3 Urban Pressure Stack in Asian Megacities

3.1 Congestion as a productivity and equity trap

Congestion is often treated as a mobility problem, but in many cities, it is also a symptom of spatial inequality: long commutes disproportionately burden residents who cannot afford proximity to jobs or high-quality transit. Comparative traffic datasets, such as the TomTom Traffic Index, can help visualize these disparities and support equity-oriented mobility interventions [13].

Visual communication tools can make this asymmetry tangible. The City of Münster's well-known space-use illustration (originating in 1991 and reproduced in later official documents) contrasts the street space occupied by the same number of people traveling by private cars versus buses or bicycles [15]. While developed in a

European context, the diagram clarifies a universal point: reallocating space and prioritizing high-capacity modes is a structural, not cosmetic, response to congestion.

3.2 Heat stress and the urban heat island

Thermal risk in megacities emerges from both climate change and local urban form. The UHI phenomenon is amplified by non-porous ground cover, diminished plant life, and human-generated thermal emissions. In Southeast Asian megacities, satellite-based studies show strong correlations between land surface temperature and the density and spatial pattern of impervious surfaces versus green space, underscoring the planning relevance of landscape configuration, not only its quantity [6].

In marginal contexts, heat risk is also an indoor comfort issue. Buildings without reliable electricity or with poor envelopes depend heavily on passive ventilation and shading. Therefore, heat mitigation must operate simultaneously at street, block, and building section scales.

3.3 Air and water pollution as a compounding risk

Air pollution remains one of the most severe environmental health risks, and the WHO's 2021 global air quality guidelines tightened recommended limits for key pollutants including PM2.5 [9]. In some Asian megacities, exposure levels still exceed guideline values by large margins, with disproportionate impacts on children, older adults, and outdoor workers.

Water pollution and plastic leakage further compound vulnerability. Riverine plastic modeling indicates that a relatively small number of rivers contribute a large share of plastic emissions to the ocean, with many high-contributing rivers located in densely populated regions [10]. Risk assessments such as Verisk Maplecroft's Environmental Risk Outlook add an additional lens by combining multiple hazards (pollution, water stress, heat, and disasters) into city-scale risk profiles [12]. For architects and planners, these findings argue for environmental systems thinking that extends beyond a single building boundary.

4 Hybrid Architectural-Urban Responses

4.1 "In-between" thresholds as climatic and social infrastructure

One of the most transferable lessons from vernacular architecture is the role of "in-between" spaces: shaded semi-outdoor thresholds, transitional courtyards, and layered boundaries that modulate climate while supporting social life. In hot-humid contexts, this logic appears as deep eaves, verandas, and permeable ground floors; in hot-arid contexts, it appears as courtyards and controlled openings. Such spaces operate as low energy "thermal negotiators" and can be embedded into contemporary programs (schools, housing blocks, transit interchanges) as the first line of comfort provision (Table 1).

Table 1. Hybrid response matrix linking key megacity challenges to vernacular lessons and appropriate modern technologies (synthesized from Gao [1])

Challenge	Traditional wisdom / spatial lever	Modern technology / infrastructure lever	Design intent (equity & resilience)
Traffic congestion & space inefficiency	Prioritize walkability and shaded thresholds; compact mixed-use; street life as 'slow mobility' support.	High-capacity public transit; demand management; data-informed multimodal planning.	Reduce time loss and land take; reclaim street space for people.
Urban heat & indoor discomfort	Deep shade, verandas/'in-between' spaces, cross-ventilation, courtyards; breathable envelopes.	Targeted efficient cooling; solar-assisted ventilation; smart controls and monitoring.	Thermal safety for vulnerable groups with low energy burden.
Air pollution exposure	Buffer zones, vegetation, porosity and filtration via layered thresholds; distance from emission corridors.	Cleaner mobility/energy; monitoring networks; indoor air-quality filtration where necessary.	Lower exposure without excluding informal livelihoods.
Water pollution & drainage stress	Permeable landscapes, retention ponds, bioswales; respect watershed lines and topography.	Decentralized treatment; smart sensing; circular water loops; leak detection.	Prevent contamination and flood risk; improve public health.
Infrastructure inequality (North–South divide)	Incremental, locally maintainable construction; community governance; low-tech robustness.	Distributed microgrids, modular renewables, storage; scalable networks.	Deliver essential services under constraint; avoid 'imported' lock-in.

Vignette 1 (*Engawa* / threshold space). In Japanese domestic tradition, the *engawa* functions as a climatic and social buffer: neither fully inside nor outside, it moderates glare, rainfall, and wind while offering an everyday platform for sitting, watching, working, and informal encounters. Translating this logic to Asian megacities under heat stress and pollution risk, 'in-between' thresholds can be reinterpreted as scalable micro-infrastructure: layered shaded edges, semi-open galleries, and porch-like corridors that slow down hot air, filter dust through vegetation and screens, and create a dignified public interface for informal livelihoods. The key is not to copy a motif, but to preserve the performative sequence of buffering, allowing buildings to negotiate environmental risk with minimal energy demand (Gao [1]).

A key implication for the North–South divide is scalability under constraint. Transitional space strategies can be implemented incrementally and do not require

perfect network reliability. They also create spatial redundancy: if mechanical systems fail, basic habitability remains possible.

4.2 Passive-to-active stacking: hybrid environmental sections

Hybrid sections combine passive logics (shading, ventilation, stack effect, thermal mass where appropriate) with targeted active support (efficient fans, localized cooling, smart controls). Solar chimneys are a representative example: by using solar-driven buoyancy to enhance ventilation, they bridge passive and active strategies and can reduce cooling demand when coupled with appropriate openings and control [5]. In practice, the performance of such systems depends on climatic suitability, occupant behavior, and maintenance regimes; the design task is therefore to create "robustness by simplicity," keeping failure modes safe and understandable.

Vignette 2 (Hibikino Campus): hybrid environmental section. Hibikino Campus (University of Kitakyushu) illustrates a practical 'passive-to-active' stacking: architectural form, shading, and controlled airflow are treated as the first line of performance, then supported by targeted mechanical systems rather than replaced by them (Fig 1). In the keynote material, the campus is presented as a living laboratory where ventilation paths, solar exposure, and building morphology are coordinated with program and comfort, enabling measurable energy savings without sacrificing everyday usability. For megacities in the Global South, the transferable lesson is governance as much as design: hybrid sections work when they are monitored, maintained, and iterated, becoming part of institutional routines and student-led experimentation (Gao [1]).

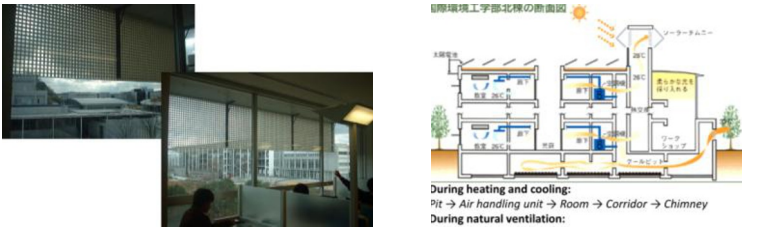

Fig. 1. Hibikino Campus as a demonstrator for hybrid environmental design: campus context (left) and ventilation/energy concept diagram (right) (adapted from Gao [1])

In urban marginal contexts, hybridization also includes material and construction choices. Incremental building processes can incorporate modular shading devices, replaceable filters, and repairable components to match local labor and supply chains.

4.3 Distributed infrastructure: microgrids and water loops

Many Global North sustainability strategies assume large, stable centralized networks. However, in parts of the Global South, resilience may be better served by distributed systems that complement, rather than replace, central utilities. At the neighborhood scale, microgrids and shared renewables can improve reliability and reduce peak

loads; at the building scale, storage and demand management can prevent comfort collapse during outages. Similarly, decentralized water loops (rainwater harvesting, greywater reuse, modular treatment) can reduce exposure to network failures and local pollution burdens.

The "hybrid" principle here is not technological novelty but systemic fit: distributed systems should align with governance capacity, financing, and maintenance realities. Hybridization therefore links spatial design, technical systems, and institutional arrangements.

4.4 Marginal architecture as a design principle

The keynote framing of "empowering the margins" encourages a shift in architectural priorities: from iconic objects to scalable improvements for everyday life [1]. Marginal architecture is not architecture for "the poor" as a category, but architecture that starts from constraints: limited capital, unreliable networks, informality, and climate exposure. It values strategies that (i) reduce dependency on brittle centralized systems, (ii) provide health and comfort benefits with low operational costs, and (iii) can be upgraded over time.

This principle reframes "beauty" as an outcome of performance and care. A shaded threshold that supports street life, a ventilation stack that reduces heat stress, or a micro-infrastructure courtyard that filters water can be both technically effective and culturally expressive.

5 AI-Enabled Tracing for Heritage and Modernization

While this paper is primarily about architectural–urban hybridity, contemporary practice increasingly requires tools for seeing change at scale. AI and computer vision provide a pragmatic bridge between field observation and city-wide monitoring, especially where documentation capacity is limited.

A systematic review of computer-vision applications for buildings highlights growing capabilities in classification, condition survey, and change detection from street-view, UAV, and satellite imagery [17]. In cultural heritage specifically, recent studies demonstrate transfer learning and data augmentation workflows for recognizing architectural components in historic buildings, enabling faster inventories and more consistent tagging across large image collections [18]. Although these methods are not replacements for expert judgement, they are positioned as the accelerators that can triage, prioritize, and reveal the patterns that would otherwise remain invisible.

We propose an AI-enabled workflow for "tracing architectural works" that can support both heritage conservation and equitable upgrading:

(1) Data acquisition: repeated street-level photography, UAV surveys, and open satellite imagery;
(2) Feature extraction: trained models for façade element detection (openings, shading devices), material proxies, and roof typologies;

(3) Temporal change detection: identifying demolition, roof replacement, and densification patterns;
(4) Risk overlay: combining outputs with heat, flood, and pollution layers to locate "hotspots of compounding vulnerability";
(5) Decision support: producing explainable maps and inventories for planners, heritage authorities, and community groups.

Ethical safeguards are essential: bias in datasets can erase minority architectures; surveillance risks must be minimized; and community consent should guide data collection in sensitive areas.

6 Discussion

The hybrid framework offers three advantages for North–South translation. First, it operates across scales, linking building sections to neighborhood infrastructure. Second, it is compatible with incremental upgrading, which matches the realities of self-built environments and constrained public finance. Third, it reconnects architectural form with environmental performance, countering a tendency to import aesthetic templates without climatic logic.

Limitations must be acknowledged. This paper does not present new empirical measurements; it synthesizes existing evidence and proposes a framework. Future work should test the framework through comparative case studies and quantify performance impacts (thermal comfort, energy demand, maintenance cost) across different settlement types. The AI workflow likewise requires careful validation and governance: accuracy targets, error auditing, and clear protocols for data stewardship.

7 Conclusion

Asian megacities exemplify the contemporary North–South urban divide: rapid growth, high exposure to congestion–heat–pollution risks, and uneven infrastructure capacity. Evidence from global datasets and remote sensing underscores that this is not a temporary "lag" but a structural condition that requires design frameworks aligned with constraint.

We argue for hybrid strategies that combine (i) "in-between" spatial thresholds, (ii) passive-to-active environmental sections, and (iii) distributed energy–water loops as scalable levers for resilience and equity. Complementing these, AI-enabled tracing can expand the capacity to document, monitor, and conserve architectural heritage while guiding modernization efforts. The overall agenda is pragmatic: connect worlds not by copying solutions, but by translating principles into locally maintainable systems that improve everyday urban life.

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