World Cities Summit 2026
Science of Cities Symposium

14th June 2026

Suntec Singapore Convention & Exhibition Centre

Abstract Proceedings

Contents

Foreword

Professor Cheong Koon Hean
Chairman, CLC Advisory Panel; Chair of the Lee Kuan Yew Centre for Innovative Cities, and Professor of Practice, Singapore University of Technology and Design; Rector of NUS College, National University of Singapore.

Cities today are operating in an environment of growing complexity and constant change. Climate risks, demographic shifts, resource constraints and evolving social expectations are placing increasing pressure on urban systems to adapt more quickly and effectively. This year's theme, "Responsive Cities," reflects the need for cities to strengthen their ability to sense change, analyse emerging patterns, and respond in ways that are timely, evidence-based and centred on the needs of people.

The Science of Cities offers an important lens through which to address these challenges. By viewing cities as interconnected systems, and by drawing on advances in data, technology and interdisciplinary research, it helps us better understand urban dynamics and develop more informed approaches to planning, governance and service delivery. Just as importantly, it helps bridge scientific inquiry and practical implementation, so that new knowledge can translate into meaningful improvements on the ground.

This year's edition of the Science of Cities Symposium brings together a diverse range of contributions from researchers and practitioners across different disciplines and urban contexts. The research abstracts featured this year were submitted by more than 40 different institutions globally, ranging from public agencies, industry leaders, research institutes, universities, and international organisations. This compilation of works reflects the breadth of inquiry and the practical orientation of the field, with work spanning the various urban use cases of AI, digital twins, mobility and infrastructure optimisation, to urban wellbeing, participatory governance, climate modelling and ecological resilience. Together, these contributions demonstrate how the science of cities is evolving as a collaborative and increasingly international effort to support more liveable, resilient and inclusive urban futures. I hope these proceedings will serve as a useful platform for knowledge exchange, connect emerging ideas across disciplines and geographies, and contribute to the translation of research to real-world urban solutions. On behalf of the Centre for Liveable Cities, I thank all contributors for sharing their work through this symposium, and I hope the ideas gathered here will stimulate further dialogue, partnerships and innovation in the collective effort to build liveable cities that are responsive to the challenges of our time.

Introduction

The World Cities Summit (WCS) Science of Cities Symposium will be held in-person on:

Date: 14th June 2026, Sunday

Time: 12pm - 6pm

Venue: Suntec Singapore Convention & Exhibition Centre, Hall 405B (Level 4)

Synopsis:

In an era of growing urban complexity, cities face challenges from climate change, demographic shifts, and resource constraints. To adapt, they must evolve from reactive governance to proactive, data-informed decision-making that anticipates citizens' needs in real time. By combining advanced analytics with human-centric design, responsive cities aim to enhance liveability and economic vitality. The Science of Cities Symposium 2026 explores "Responsive Cities" through two panels: one on technological innovation and integration, and another on community impact. The symposium examines how smart city initiatives and data-driven systems can create adaptable, resilient, and inclusive urban spaces that are efficient and liveable.

Panel 1: From Sensors to Solutions – Data-driven Urban Operating Systems

As cities evolve into complex digital ecosystems, the integration of data-driven systems with urban governance has become paramount, representing a fundamental shift from traditional siloed management to interconnected, real-time decision-making systems. Modern cities generate unprecedented volumes of data through sensors, digital services, and citizen interactions, creating opportunities for researchers and agencies to develop innovative approaches to urban management that can anticipate and address challenges before they escalate. This systemic integration enables real-time responsiveness to citizen needs whilst facilitating evidence-based decision-making and optimal resource allocation in urban planning and service delivery.

This panel examines how these systems are reshaping our approach to urban planning and management, and how built environments may dynamically adapt to changing conditions.

Panel 2: From Solutions to Society – Human-centred Smart Cities

Government agencies implementing smart city initiatives face the critical challenge of ensuring technology serves community needs and strengthens social cohesion rather than creating digital divides or undermining local connections. The measure of success for smart city initiatives lies not in the sophistication of technology deployed, but in how effectively it enhances community resilience, facilitates meaningful social interaction, and improves quality of life for all residents – goals that are especially critical in this era of unprecedented urban challenges. Robust frameworks are required, to evaluate whether technology implementations and investments are delivering social benefits and creating more inclusive, participatory urban governance.

This panel examines how smart city initiatives can be designed and implemented with community interests at their core, exploring the intersection of digital innovation and social sustainability.

Through the presentations, panel discussions, and posters, the symposium will serve as the academic platform of WCS, where insights from scientific knowledge and research methodologies may connect with WCS audience of industry practitioners and city leaders, kickstarting cross-institute and sectoral evidence-based innovations to address current and emerging urban challenges.

Symposium Programme

Time (GMT+8)	**Programme**
12.00-1.30pm	**Science of Cities Poster Exhibition and Networking Lunch** (at Hall 405B)
1.30–1.40pm	**Opening Address by Professor Cheong Koon Hean** (at Hall 405B)
Panel 1: From Sensors to Solution – Data-driven Urban Operating Systems	
1.40–3.20pm	**K1.1:** Reimagining the City with AI *Dr Ramine Tinati* **K1.2:** Making the Intangible Tangible: Towards Reasonable Urban Solutions *Prof Pieter Herthogs* **O1.1:** Tooling for Urban Resilience – How to Make Cities Robust Against Shock *Prof Jörg Rainer Noennig* **O1.2:** Building an Integrated Modelling & Simulation Ecosystem on the ePlanner *Kelvin Li Wenhui* **O1.3:** Classifying Transportation Decarbonisation Policies and Profiling Global Cities: The Potential of Artificial Intelligence *Dr Alex Li Shengxiao* **O1.4:** Atlas of Healthy Streets: Benchmarking Health Determinants Across Spanish Cities *Olivia Poston* **O1.5:** From Urban Models to Decisions: A Risk-aware Decision Intelligence Layer for Data-driven City Planning *Mr Ivan Beliaev* **Panel discussion** (moderated by keynote speakers)
3.20–3.40pm	Networking Tea Break
Panel 2: From Solutions to Society – Human-centred Smart Cities	
4.10–5.50pm	**K2.1:** Sustainable Proximities for a High Quality of Life *Prof Carlos Moreno* **K2.2:** Future-Positive Cities: Using AI to Design for Climate, Ecology, and Liveability *Prof Dr Thomas Schroepfer* **O2.1:** Capturing Eye-level Urban Experiences to Enhance Community Well-being *Prof Louise Vogel Kielgast* **O2.2:** Singapore's Beneficiary-centric Approach in Implementing Geospatial Solutions for Social Good in the Socio-healthcare Sector *Ng Siau Yong* **O2.3:** AI for Future Cities: A Foresight Led Exploration into the Opportunities and Risks of AI Deployment in Our Cities *David Moran* **O2.4:** From Solutions to People: Social Media Narratives and Emotional Governance in People-centred Urban Renewal *Dr Bowen Zhou* **O2.5:** Living Cities: Nature-inspired Blueprints for Collaborative, Human-centred Smart Cities *Dr Samantha Hayes* **Panel discussion** (moderated by keynote speakers)

Panel 1: From Sensors to Solutions – Data-driven Urban Operating Systems

Keynote Synopsis

K1.1

Reimagining the City with AI

Dr Ramine Tinati

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In this presentation, we will explore the advancements across the various applications of AI that support the ever evolving urban landscape where we live, work, and play. We will explore from topics such as the use of world models to transform the way we design and plan our cities, to the use of material sciences to make our environment more sustainable and long lasting.

K1.2

Making the Intangible Tangible: Towards Reasonable Urban Solutions

Prof Pieter Herthogs

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This presentation emphasises the significance of intangible ideas and concepts—think resilience, scenarios, or decisions—to our efforts to shape and govern cities. Responsive urban operating systems should help integrate our shared data of the tangible and our shared understandings of the intangible. In this way, such reasonable technologies simultaneously support the use of urban data and the communication of urban meaning.

Through diverse examples, including ways to audit the results of LLM street surveys and an interface to map stakeholders' scenario assumptions, this talk demonstrates how formal knowledge models can make complex city systems more explainable and actionable, for humans and machines alike.

Abstracts – Oral Presentations

O1.1

Tooling for Urban Resilience – How to Make Cities Robust Against Shock

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The work of Digital City Science (DCS) at HafenCity University Hamburg focuses on the creation of data-driven tools to address complex challenges in urban development. Over the past 10 years, DCS has put forward a "science of tooling" – a systematic and rigorous process that allows fast transition from conceptualisation to rapid prototyping and technical implementation. The resulting solutions help urban decision makers in a diversity of application fields, e.g. urban construction, mobility planning, migration management, or rescue operations. A contemporary key challenge is the increasing demand for resilience on the level of entire cities as well as on district and neighbourhood level. Climate change, speculative technologies, as well as social and political stresses expose cities to ever more natural catastrophes, technical hazard, or military conflicts. On the background of recent and ongoing co-operations in the context of urban recovery planning in Ukraine, DCS has put forward new digital instruments that enable a reliable assessment of urban vulnerabilities, and support resilience-oriented planning and decision making. For this end, DCS has federated the plethora of existing resilience models, enhanced them with new indicators and dimensions, and deployed a comprehensive digital check-up for cities that not only allows a clear indication of risks and vulnerabilities but also the targeted development of responsive planning measures. The prototypical tool – a digital platform linking GIS based city models to resilience assessment and impact metrics – has been tested and applied in Ukrainian cities, and is currently replicated for more general application in the German / European context. The tooling process as well as the implementation and application of the platform have shown that strengthening the robustness of urban systems has become a key ambition of smart city ventures – a demand that can be properly addressed by advanced urban data science and technology.

Keywords: City-tech, Digital Tooling, Urban Resilience, Vulnerability Assessment

O1.2

Building an Integrated Modelling & Simulation Ecosystem on the ePlanner

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This presentation highlights how the Urban Redevelopment Authority, as the Centre of Excellence for Urban Planning & Design Technology (URBEX) in Singapore Government, has been transforming land use planning into a more data-driven and agile practice, through the development and use of data, analytics and Modelling & Simulation (M&S) tools. URBEX has developed the ePlanner, an easy-to-use web-based 2D-3D geospatial platform to mainstream these capabilities for agencies' use, without the need for specialised software or know-how. Offering more than 200 data layers and 50 tools, it is used by over 1800 users across 40 agencies today. To continue pushing boundaries, URBEX is building up a suite of advanced M&S capabilities on the ePlanner to support complex scenario planning. For example, users can now leverage Procedural Modelling tools on the ePlanner to computationally generate multiple 3D urban scenarios rapidly. A Wind Simulation prototype is also available on the ePlanner for users to test development plans for their impact on windflow and identify measures to improve outdoor thermal comfort. With increasing complexities in land use planning, these capabilities (when fully developed) empower decision-makers to quickly evaluate different development scenarios, weigh trade-offs, and optimise outcomes before plan implementation.

Keywords: ePlanner, Modelling & Simulation, URBEX

O1.3

Classifying Transportation Decarbonisation Policies and Profiling Global Cities: The Potential of Artificial Intelligence

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Transportation and logistics account for nearly a quarter of global carbon emissions, with cities playing a central role in decarbonisation. Policy strategies vary widely—car-dependent cities like Los Angeles often emphasise vehicle electrification, while cities such as London prioritise public transit and active travel. This study investigates the potential of Artificial Intelligence, particularly ChatGPT, to classify transportation decarbonisation policies and profile cities based on their strategic focus. We analyse more than 2,500 sentences from 43 climate action plans within the C40 city network using human coding and variations of ChatGPT using program engineering. We assess the strengths and limitations of each approach in identifying policy tools and categorising cities. Our findings reveal variations in policy priorities across global cities and highlight how different methods shape classification outcomes. In particular, we evaluate ChatGPT's ability to assist researchers and policymakers in identifying coherent policy packages and positioning cities within broader decarbonisation typologies. This work also explores how integrating AI with machine learning and qualitative techniques can enhance the accuracy and efficiency of policy analysis in climate action and urban analytics research.

Keywords: Transportation, Decarbonisation, Global Cities, Artificial Intelligence, Classification, Text Analysis

O1.4

Atlas of Healthy Streets: Benchmarking Health Determinants Across Spanish Cities

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Cities play a central role in shaping health and well-being. Everyday exposure to environmental conditions, access to services, mobility patterns, and social infrastructure influences physical and mental health outcomes. As urban populations grow and cities face increasing pressures from climate change, demographic shifts, and social inequality, there is an urgent need for tools that translate complex health relationships into spatial insights that support evidence-based decision-making. The objective of this paper is to present the Atlas of Healthy Streets, a benchmarking framework developed to assess how built environment conditions support or constrain health and to enable comparison across cities. The methodology uses a street-network analysis model in which cities are analysed as contiguous 50-metre street segments, allowing granular assessment of health determinants in relation to connectivity, continuity, and everyday movement patterns. Spain is selected as the pilot geography for its diversity of urban forms, climatic conditions, and data availability, and sixteen pilot cities are sampled across sixteen communities to support comparative analysis without regional bias. The framework integrates multiple layers of environmental, social, and infrastructural data and evaluates determinants, including green and blue elements, active-lifestyle infrastructure, access to key amenities, playfulness, and relief from sensory stressors such as traffic and pollution. Preliminary findings indicate substantial variation across cities in the continuity and accessibility of health-supporting conditions, and within cities in the clustering of low-performing street environments along major mobility corridors and peripheral growth areas. The paper concludes that street-network benchmarking offers a practical basis for identifying transferable patterns, diagnosing gaps in everyday health provision, and prioritising targeted interventions where marginal investment may yield disproportionate benefit. The Atlas is presented as a research-based prototype intended to evolve through iterative validation and improved datasets, while offering immediate strategic value for responsive urban policy, public health planning, and climate adaptation.

Keywords: City Science, Data, Network Analysis, Public Health, Spatial Inequalities, Urban Planning

O1.5

From Urban Models to Decisions: A Risk-Aware Decision Intelligence Layer for Data-Driven City Planning

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Cities increasingly rely on digital twins, simulation platforms, and machine learning models to support planning analysis of accessibility, heat exposure, land use performance, and service provision. However, planning decisions such as zoning changes, transport investments, green infrastructure deployment, and redevelopment strategies are still made across fragmented systems. As a result, trade-offs between competing objectives, uncertainty across future conditions, and the long-term consequences of irreversible spatial and financial commitments are often negotiated informally and remain difficult to justify transparently. This research proposes an urban decision intelligence layer that operates above existing analytical tools rather than replacing them. Urban planning is formalised as a structured multi-objective decision problem in which alternative interventions are evaluated as portfolios across uncertain future scenarios. The methodology integrates heterogeneous outputs from digital twins, simulation environments, and data-driven predictors by mapping them to shared decision metrics and admissible KPIs, without modifying their internal assumptions or workflows. A dedicated decision layer synthesises these inputs to compare intervention portfolios by expected performance, sensitivity to uncertainty, and potential lock-in effects. Decision outputs are expressed as structured decision packages that document baseline conditions, selected strategies, rejected alternatives, underlying assumptions, and key risk areas. A planner-facing explanatory interface supported by large language models assists interpretation while preserving decision authority with human planners and institutions. Feasibility is demonstrated across multiple urban districts using planning and building datasets, spanning baseline representation, scenario construction, portfolio evaluation, and decision synthesis. The decision layer supports near to medium-term planning decisions related to building energy performance, thermal exposure mitigation, and urban intervention prioritisation. Initial findings indicate that alternative approaches to uncertainty handling and priority weighting can alter which planning strategies appear preferable. By shifting attention from prediction to decision integration and accountability, this work contributes a governance-oriented foundation for more transparent and adaptive data-driven urban planning systems.

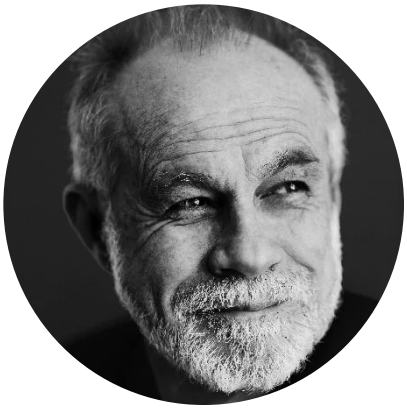
Keywords: Decision Intelligence, Digital Twins, Large Language Models, Risk-aware Planning, Urban Governance, Urban Operating Systems

Panel 2: From Solutions to Society – Human-centred Smart Cities

Keynote Synopsis

K2.1

Sustainable Proximities for a High Quality of Life



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Urbanisation and car-dependent planning have increased emissions, inequality, and fragmented access to essential urban services. Cities are increasingly shifting from conventional zoning toward mixed-use, human-centred neighbourhoods where daily needs are accessible by foot or bicycle – the 15-minute city. Yet, existing research often isolates urban functions and lacks an integrated proximity implementation framework across context. Drawing from recent findings from data-driven spatial analysis and participatory co-creation workshops, this address explores how proximity planning extends beyond distance to accessibility, inclusion and stakeholder engagement, multi-functionality, and time. The proposed HQSL proximity index presented supports scalable, participatory, and adaptable proximity assessment across diverse global urban contexts.

K2.2

Future-Positive Cities: Using AI to Design for Climate, Ecology, and Liveability

Prof Dr Thomas SCHROEPFER

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As cities confront the interconnected challenges of climate change, biodiversity loss, and rapid urbanisation, the question is no longer whether cities will grow, but what kind of systems they will become. While sustainable urban development has traditionally focused on reducing negative impacts, there is an increasing need to move beyond mitigation towards approaches that actively create environmental, social, and economic value. This presentation introduces the concept of future-positive cities—urban environments that contribute to climate adaptation, ecological regeneration, and human well-being while remaining economically resilient and attractive. Drawing on research from the Singapore University of Technology and Design and the Future Cities Laboratory Global at the Singapore-ETH Centre, it explores how artificial intelligence and data-driven methods can help bridge the gap between design intentions and urban outcomes by enabling planners, designers, and policymakers to better understand the consequences of decisions before they are implemented. Using examples from high-density urban environments, the presentation demonstrates how new analytical and AI-supported approaches can improve outdoor comfort, walkability, accessibility, social interaction, and public-space use while simultaneously advancing environmental performance and resilience. Rather than focusing on technology for its own sake, it argues that the greatest potential of AI lies in supporting more integrated, human-centred urban decision-making.

Abstracts – Oral Presentations

O2.1

Capturing Eye-level Urban Experiences to Enhance Community Well-being

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Smart city programs are often evaluated through technical performance metrics—mobility efficiency, service response times, or sensor coverage—yet their most significant impacts are frequently social: whether people feel safe, welcomed, connected, and able to influence the places they inhabit. This paper proposes an evaluation approach that foregrounds community wellbeing and social sustainability through lived experience data, drawing on the Gehl Eye Level City app developed within the research project *Urban Belonging*.

Urban Belonging aimed to understand where and why people experience a sense of belonging, and to explore new ways of rethinking citizen participation. The project developed a participatory methodology centred on map-making and photography. Through the Eye Level City app, residents document how different parts of the city make them feel by combining geolocated photographs with short, in-the-moment reflections. Capturing everyday emotional responses—joy, calm, stress, discomfort, or belonging—the tool creates a qualitative evidence base that complements conventional urban indicators and reveals how spatial conditions are perceived across diverse groups, times, and contexts. Findings show that belonging depends on a hierarchy of needs being met, and that access to nature emerged as a key factor across minority groups, highlighting the importance of equitable green space in fostering inclusive cities.

The research further demonstrates the need to give citizens real agency by inviting them to be more than data points: participants interpret experiences, frame problems, and contribute to solutions in processes that are genuinely collaborative. The app lowers barriers to engagement by enabling asynchronous participation in citizens' own words, directly from the streets where experiences occur.

We discuss how curated emotional maps and thematic syntheses can translate lived experience into actionable design opportunities—spaces that not only function well, but also feel supportive and welcoming. Based on continued development and application of the Eye Level City app in planning and design projects, we argue that smart city initiatives are most effective when they measurably enhance perceived wellbeing and belonging while strengthening the social infrastructures that sustain participation and resilience.

Keywords: Emotions in Cities, Participation Methods, Innovation, Citizen Science, Accountability in Planning and Design

O2.2

Singapore's Beneficiary-centric Approach in Implementing Geospatial Solutions for Social Good in the Socio-healthcare Sector

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While smart cities globally have achieved mainstream geospatial adoption in the infrastructure-environment sector (Biswas & Dygas, 2023), the socio-healthcare sector is unacquainted with geospatial technologies. The Singapore Land Authority's initiatives in socio-healthcare sector provide novel lessons in practical implementation of geospatial solutions for social good. Two examples of the Living Asset Map (LAMP) and the Barrier-Free-Access (BFA) mapping are highlighted to show how geospatial solutions can achieve social impact.

Firstly, the collaboration with SingHealth Community Hospitals in LAMP promotes preventive health by encouraging community participation amongst elderly patients. The community capture activities onto LAMP, which builds community networks to support preventive healthcare. Patients are connected to community activities based on proximity, making it inherently geospatial and patient-focused. The first example shows how implementing the patient-focused geospatial solution with data from the community supports preventive healthcare.

Secondly, the mapping of Barrier-Free-Access (BFA) paths in Singapore promotes inclusive mobility of persons with disabilities (PwDs). Although barrier-free infrastructure exists, they need to be discoverable by PwDs. The mapping of BFA paths complements existing infrastructure as it provides a more complete first-and-last-mile wayfinding that caters to their needs. As of November 2025, 1500km out of 5000km of BFA paths have been mapped, with participation of wheelchair users to test them. The second example shows how the geospatial solution supports inclusive mobility by being centred on the PwDs as it enables them to navigate seamlessly.

Therefore, given that many social needs are location-based and inherently geospatial, these two initiatives provide examples in the implementation of geospatial solutions to achieve social impact. The lesson learnt from the two examples is that the geospatial solutions 1) relied on building new data from the community and 2) being focused on the beneficiary to achieve social good. This opens possibilities for wider expansion to other socio-healthcare use cases to mainstream geospatial adoption.

Keywords: Barrier-free Access, Beneficiary-centric, Community Participation, Geospatial Solutions, Healthcare Mapping, Social Impact

O2.3

AI for Future Cities: A Foresight Led Exploration into the Opportunities and Risks of AI Deployment in Our Cities

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Cities are entering a period of rapid technological change as artificial intelligence (AI) becomes increasingly embedded in urban systems. This transformation presents significant opportunities for more efficient, creative and responsive approaches to city design and governance, but also introduces complex risks that vary across local and global contexts. The long-term implications of widespread AI deployment, particularly over a ten-year horizon and beyond, remain uncertain and require careful examination. Arup's AI for Future Cities research series investigates these issues by exploring the potential outcomes AI may generate across key urban domains, including planning and design, energy, water, transport, nature and workplaces. The aim is to understand how AI can support better outcomes for people, the planet and place, while also identifying emerging challenges and unintended consequences. The research contains six domain-focused studies. Each combines a literature review, horizon scanning of future trends, expert interviews and case studies. These inputs are synthesised into a visual representation imagining what a City of 2035 might look like under different AI-enabled scenarios. Several cross-cutting insights emerge from the series. First, a recognition that AI should strengthen rather than replace human judgement, aiding creativity and critical thinking, where retaining a human in the loop is essential for responsible decision-making. Second, advances in predictive analytics and real-time monitoring offer powerful tools for climate resilience and resource management. Third, technologies such as digital twins and rapid generative design create new opportunities for participatory engagement and iterative planning. Finally, the ethical risks associated with bias, privacy and opaque algorithmic processes require robust data practices and clear accountability mechanisms. Across all domains, the research highlights some common recommendations: the need for high-quality, interoperable data; strong governance and ethical frameworks; and collaboration across sectors and communities to ensure AI is deployed in the best interests of our people, planet and places.

Keywords: Artificial Intelligence, Foresight, Future City, Governance, Horizon Scan, Participatory

O2.4

From Solutions to People: Social Media Narratives and Emotional Governance in People-centred Urban Renewal

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This paper investigates how social media data can support people centred smart city governance by revealing the emotional and experiential dimensions of urban renewal. Anchored in Lefebvre's theory of the production of space, the study conceptualises urban renewal as an interaction between conceived space, defined as symbolic representations constructed by government agencies, planners, and mainstream media, and lived space, referring to the everyday practices, perceptions, and emotional experiences expressed by residents and visitors. While contemporary smart city initiatives often prioritise technological efficiency, spatial optimisation, and heritage branding, they frequently overlook how urban interventions are actually perceived, felt, and evaluated by local communities. This study argues that social media platforms function as urban emotional sensors, capturing real time collective sentiments that are essential for responsive, inclusive, and socially sustainable governance.

Using a mixed method narrative analysis of Weibo data, the study constructs two complementary datasets. The first comprises official and professional accounts, including verified government media, commercial brands, and cultural institutions, representing top-down spatial narratives. The second consists of posts generated by ordinary users and local residents, reflecting bottom-up experiential narratives. We apply textual analysis techniques to measure narrative similarity between these two groups, enabling a systematic comparison between planned representations and lived experiences of urban space. The empirical cases of Tianzifang, Yuyuan Road, and Fuxing Island in Shanghai reveal a persistent misalignment between official development and cultural heritage-oriented narratives and public experience-oriented narratives. Whereas authorities emphasise historical value, symbolic identity, and place branding, social media users focus more strongly on walkability, lifestyle atmosphere, consumption experiences, and emotional attachment.

The findings suggest that data driven emotional governance can enhance smart city strategies by incorporating affective feedback into urban decision-making processes. By translating collective emotions and lived experiences into actionable knowledge, social media analytics can strengthen community participation, improve policy responsiveness, and support more inclusive and people centred urban renewal. This study contributes a methodological framework for evaluating smart city initiatives through emotional and narrative data, thereby aligning technological solutions with social resilience and community wellbeing.

Keywords: People-centred Smart Cities, Social Media Analytics, Emotional Governance, Urban Renewal

O2.5

Living Cities: Nature-inspired Blueprints for Collaborative, Human-centred Smart Cities

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As cities rapidly adopt smart technologies, it is important that these tools genuinely empower people, enhance wellbeing, and build inclusive, resilient communities. This session explores how human-centred smart ecosystems can be designed by learning from nature's most adaptive and participatory systems. Using Dhun, an 'ecology first' master-planned community development as a case study, the session combines emerging practice with biological strategies to propose a practical framework for collaborative, community-led urban development that strengthens adaptive social capacity.

Conventional approaches to resilience in the built environment typically prioritise strength, stability, and predictability - designing systems that resist disturbance and minimise change. In contrast, resilience in living systems is underpinned by dynamic non-equilibrium, decentralised sensing and real-time feedback loops, internal and automatic repair, and multi-functionality.

Drawing on biological strategies, the session examines how distributed decision-making and collective intelligence can emerge without central authority. Ant colonies rely on local signals and quorum-based decisions, while bee swarms converge on optimal outcomes through shared sensing and iterative feedback. We translate these principles into civic and environmental technologies, including participatory budgeting, issue-reporting and mapping platforms, and large-scale public planning tools, alongside place-based ESG data portals currently being developed for the case study community.

The session further explores how collective sensing and diversity can be supported through integrated, place-based data platforms that combine environmental performance, mobility, comfort, safety, and lived experience. Hybrid engagement models linking digital tools with in-person collaboration, living labs, and community storytelling are proposed to strengthen trust, inclusion, and local stewardship.

Finally, we reference a nature-inspired evaluation framework for smart city initiatives, focusing on inclusivity, social and ecological adaptive capacity, trust and legitimacy, regenerative ecological performance, and community wellbeing.

Keywords: Biomimicry, Collective Intelligence, Decentralised Governance, Participatory Technologies, Urban Resilience

Poster Abstracts

P1.01

Mapping Urban Biodiversity in 3D: LiDAR-Driven Ecological Connectivity for High-Density Cities

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High-density urban development in cities such as Singapore fragments ecosystems into small habitat patches isolated by urban infrastructure, creating a critical dimensional gap in ecological planning, where traditional two-dimensional (2D) connectivity models fail to capture vertical habitat stratification and volumetric human disturbances. This research addresses this gap by proposing a novel three-dimensional (3D) ecological connectivity modelling framework that integrates aerial LiDAR point clouds with remote sensing datasets to quantify biodiversity flows through the full urban volume. Using deep learning pipelines, LiDAR point clouds are semantically segmented and voxelised to construct species-specific 3D resistance volumes reflecting buildings, trees, skybridges, and vertical green infrastructure. Connectivity through this urban matrix is then simulated using a 3D-informed circuit theory model implemented in Omniscape. The outputs identify critical multi-level corridors, vertical pinch points, and zones where biodiversity movement is most constrained by high-rise development. The results reveal how vertical urban form fundamentally reshapes ecological connectivity and demonstrate that multi-tiered greenery and elevated landscapes can act as high-value ecological bridges in dense cities. In addition to supporting biodiversity movement, the identified 3D ecological corridors indicate where connected vegetation structures may also contribute to carbon sequestration and urban heat island mitigation, particularly through increased canopy continuity, shading, evapotranspiration, and the integration of vertical green infrastructure. These findings provide urban planners, park agencies, and development authorities with a quantitative basis to prioritise where green infrastructure, sky gardens, and ecological corridors will deliver the greatest ecological and climate-related benefits. By embedding biodiversity dynamics into a 3D, AI-driven digital twin of the city, the framework enables a new class of decision-support tools for planning a resilient "City in Nature", allowing ecological performance to be evaluated alongside density, transport, and climate adaptation in high-rise urban environments.

Keywords: Urban Biodiversity, Ecological Connectivity, Green Infrastructure, Lidar, Circuit Theory, Urban Digital Twin

P1.02

Personalised Dynamic Pricing for Residential Demand Response: Integrating Online Learning and Bilevel Programming

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Dynamic pricing has been widely adopted to activate residential demand response (DR). However, its effectiveness is fundamentally constrained by pronounced household heterogeneity: consumers exhibit diverse price elasticities of electricity demand that vary over time and are shaped by preferences, comfort requirements, and daily routines. As a result, conventional uniform dynamic pricing schemes are inherently inefficient and often fail to achieve sustained reductions in peak load at a reasonable cost. To overcome this limitation, this paper proposes a Personalised Dynamic Pricing (PDP) mechanism that explicitly leverages consumer heterogeneity by delivering individualized price signals that vary over time and are tailored to household specific elasticities. The PDP scheme is built upon a tightly coupled interaction between online learning and bilevel optimisation. Specifically, at each iteration, an online learning module updates estimates of the price elasticities of individual consumers based on historical price signals and observed consumption responses. These updated elasticity parameters are then embedded into a bilevel optimisation framework, where the upper-level problem determines the optimal personalised prices to minimise total system cost subject to network constraints, and the lower-level problem models household responses by minimising individual electricity expenditure and discomfort. The resulting optimal prices are subsequently implemented, and the observed consumer responses are fed back into the online learning module to refine the elasticity estimates. This iterative feedback loop continues over time, enabling the pricing strategy to progressively adapt to heterogeneous consumer behaviour that evolves over time. Numerical experiments with an energy community with heterogeneous price elasticity demonstrate that the proposed PDP mechanism consistently outperforms benchmark schemes, including Time-of-Use (ToU) pricing and uniform dynamic pricing (UDP), achieving lower system costs, stronger participation, and more effective peak reduction. Moreover, the learning enhanced framework achieves rapid convergence in daily system cost, with cost performance approaching the full information benchmark within approximately five days under the assumption that consumer elasticities are perfectly known, thereby underscoring its strong potential for real world deployment.

Keywords: Residential Demand Response, Personalised Dynamic Prices, Bilevel Programming, Online Learning, Bayesian Neural Network

P1.03

Buildings.Sg: An Integrated Data-Driven Platform for Urban Building Energy Modelling, Carbon Emissions Mapping and Benchmarking in Singapore

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Cities and municipalities often face challenges in scaling building-level energy and carbon assessments to district- or city-wide analyses, due to incomplete datasets, inconsistent input quality, and the absence of standardised benchmarks. This study introduces Buildings.sg, an open-source Urban Building Energy Modelling (UBEM) and carbon mapping platform for Singapore. The platform integrates data processing, machine learning–based archetype prediction, energy simulation results, and geospatial visualisation, with EnergyPlus simulation-ready templates freely downloadable. A predictive model achieved 79% accuracy in classifying missing building archetypes, enabling scalable applications across urban contexts. Parametric shoebox models that underpin the energy simulation results were calibrated using local occupancy patterns and validated against government-published Energy Use Intensity (EUI) benchmarks to ensure accuracy. The platform also enables visualisations of operational and embodied carbon emissions, building performance data, and green building certifications for approximately 120,000 buildings, supporting the identification of priority intervention areas. Built on a modular Grasshopper workflow, Buildings.sg is adaptable to different cities or climates by replacing local input data, bridging the gap between UBEM research and practical planning. By enabling scenario-based carbon mitigation analyses and benchmarking, the framework supports policymakers, urban planners, and researchers in data-driven decision-making. Buildings.sg is fully open source on GitHub, enhances transparency, replicability, and effectiveness in urban decarbonisation planning, offering a robust and scalable tool for cities seeking evidence-based strategies toward climate targets.

Keywords: Urban Building Energy Modelling (UBEM), Machine Learning, Energy Simulation, Carbon Mapping, Building Decarbonisation, Open-source Platform

P1.04

A Science-Based Playbook for Wind-Driven Rain Mitigation in Industrial Buildings in Singapore

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In pursuit of sustainable building, JTC industrial developments prioritise natural ventilation (NV) as a key strategy in the design of spaces to enhance occupant well-being and minimise operational energy. However, NV spaces often present an increased risk of Wind-Driven Rain (WDR) ingress. Despite implementing standard rain mitigation measures – such as double-bank performance louvres, and overhangs – there has been a documented increase in WDR incidents within critical NV spaces such as corridors, lift lobbies, tenant production areas, and M&E rooms. Coupled with intensifying rainfall and unpredictable weather patterns driven by climate change, there is an increasing need for a performance-based approach to evaluate the effectiveness of current rain mitigation strategies.

This paper presents a computational framework developed to conduct large-scale WDR simulations and accurately quantify WDR ingress across diverse industrial geometries. Through analysis of 10 years of NEA meteorological data from 32 weather stations, regional wind and rain patterns were established and used as reliable input parameters for WDR simulations. By leveraging on an improved Computational Fluid Dynamics (CFD) solver and executing simulations on an HPC (High Performance Computing) cloud platform, the study evaluated over 1,000 simulation scenarios across three massing typologies and six façade systems with multiple design parameter combinations. Performance metrics including Local Catch Ratio, wetness thresholds, and Depth of Penetration were established as parameters to quantify WDR ingress.

The research culminates in a "Design Playbook" – a data-driven toolkit designed to guide architects in implementing WDR mitigation strategies in industrial buildings. The Playbook highlights the impact of building massing on WDR and categorises façade typologies based on their efficiency in mitigating rain across varied wind speeds. The Playbook further serves as a practical reference containing regional wind speed return periods for site-specific WDR simulations, established rain tolerance levels for specific industrial spaces, and targeted design recommendations for WDR mitigation. This study provides a scalable blueprint for future WDR studies across other building typologies in Singapore.

Keywords: Computational Fluid Dynamics (CFD), Climate Resilience, Design Playbook, Eulerian Multiphase (EM), Industrial Development, Wind-driven Rain (WDR)

P1.05

A Generalisable Spatio-Temporal Machine Learning Framework for Modelling Urban Carpark Demand

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Urban trip generation estimates are essential for transport planning, yet existing survey-based methods are expensive, infrequent, and limited in spatial and temporal detail. This study develops a generalisable and interpretable data-driven framework for predicting trip generation at public carparks using routinely collected open-source data. We use high-frequency parking lot availability records from Singapore as a proxy for vehicle movements and combine them with carpark capacity, land-use composition, socio-demographic characteristics, and public transport accessibility indicators. To improve generalisability, carparks are grouped using unsupervised clustering based on capacity, and neighbourhood context is incorporated using a nearest-neighbour approach across structurally comparable carparks. Predictive models are evaluated using both conventional holdout evaluation and strict GroupKFold validation by carpark to assess robustness when predicting demand at previously unseen carparks. Under random holdout evaluation, the baseline model achieves an R^2 of 0.90, while structure-aware models using clustering and neighbourhood information maintain stable performance under GroupKFold evaluation, with R^2 values around 0.63, indicating generalisation to unseen locations. Scenario-based analyses demonstrate that the model performs reliably in high-capacity residential carparks, where increases in population and parking supply produce consistent changes in predicted trips, while larger errors are observed in low-capacity and commercially subzones, where higher concentrations of firms and commercial activity are associated with more heterogeneous and less predictable trip patterns compared to residential areas. To ensure interpretability, we use SHapley Additive exPlanations (SHAP) analysis to deconstruct the model's behaviour. This reveals parking capacity as the primary determinant across the network, while enabling localised explanations of individual carpark predictions. The results show that combining structural clustering with neighbourhood similarity produces a scalable and interpretable data-driven alternative to traditional trip generation approaches, providing actionable insights for urban planners and policymakers by ensuring generalisability to diverse urban environments.

Keywords: Carpark Demand, Machine Learning, Spatial Modelling, Trip Generation, Urban Mobility

P1.06

Understanding Urban Sustainability Trade-Offs in Singapore Using Graph Neural Networks with Explainable AI

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Urban development in high-density cities must balance economic growth, environmental performance, and social well-being, yet how urban morphology mediates these competing priorities remains poorly quantified and (often) methodological obscured. This study introduces a data-driven framework for diagnosing and optimising environmental and socio-economic trade-offs in dense urban environments. We introduce two composite metrics – the Environmental Cost and Stress Index (ECSI) and Socio-Economic Vitality Index (SEVI) – and apply them to Singapore as a high-density urban testbed. Using twelve key urban morphological features, we train a Graph Neural Network (GNN) and employ SHAP-based explainable AI to uncover non-linear and spatially interdependent relationships between urban morphology and performance outcomes. Pareto frontier analysis identifies three distinct urban archetypes: *Economic Anchors*, which maximise socio-economic vitality at higher environmental cost; *Ecological Buffers*, which minimise environmental impact but exhibit lower social activity; and *Balanced Transitions*, which represent synergistic configurations that achieve an equitable stabilisation across both dimensions. Results reveal that proximity to the central business district and to mass transit stations is the dominant performance driver, establishing a structural ceiling on attainable ECSI–SEVI combinations. Greenery ratio (NDVI) and neighbourhood-averaged building height (NB_AHI) emerge as the most influential modifiable variables. Spillover analysis demonstrates that retrofitting high-connectivity "Inefficient Hubs" generates environmental spillover effects up to 23.4 times greater than those of equivalent interventions in peripheral nodes, underscoring the strategic value of topology-aware urban regeneration. These findings provide planners with actionable, site-specific benchmarks for morphological intervention, offering a scalable toolkit to guide future development toward a resilient balance between ecological health and socio-economic vitality.

Keywords: Environmental and Socio-economic Trade-offs, Explainable Artificial Intelligence, Graph Attention Networks, Urban Morphology, Urban Sustainability

P1.07

Computational Geometry Assisted Zero-Shot Building Floor Count Extraction using Large Vision Language Reasoning Model

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Natural hazards researchers, engineers and government agency officers gather information about buildings and other infrastructures in areas to study, understand and prepare for the potential damage caused by natural hazards. Human surveyors are slow and expensive for large areas. Automated building recognition methods such as BRAILS, utilise supervised machine learning to extract information such as the number of floors, roof types, year of construction, etc. from satellite and street-view images. Newer methods from BRAILS++, OpenFACADES and several others utilises the zero-shot capability of vision and language models (VLMs) to extract building attributes with just one model and without the need of further data annotations and model training. However, such methods are still unable to perform well in challenging visual scenarios where the target building is among multiple buildings, partial occlusion, small target buildings in front of or adjacent to large buildings, explore unblocked viewing angles or panorama locations, etc. In this study, we propose utilising Large Vision-Language Reasoning Models (VLMs) assisted by deterministic computation geometry to perform zero-shot building floor count extraction from satellite imagery and street-view imagery (SVI). Our workflow reduces hallucination and fluke results under challenging visual scenarios. Our workflow also generates individual 3D mesh of each building using SAM3 for use in advanced 3D natural hazards simulators. Preliminary results show that our workflow achieves a floor count accuracy of 77% using deterministic computational geometry assisted GPT-5.2, whereas out of the box GPT-5.2 and GPT-4o achieves 54.7% and 48.8% respectively. Our team is working to improve the workflow and algorithms aiming to achieve floor count accuracy of 82%-87%. Consequently, our proposed method enhances the AI workflow that could be a low-cost and reliable augmentation of human surveyors that mimics human level capabilities for building floor count extraction in the natural hazards engineering domain.

Keywords: Natural Hazards Engineering, Street-view Imagery, Computer Vision, Spatial Reasoning

P1.08

Heavy Freight Electrification: A Data-Driven Infrastructure Challenge

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The electrification of urban freight and heavy-duty vehicles is increasingly viewed as a critical pathway for reducing transport emissions in dense cities. However, unlike passenger vehicle electrification, heavy-duty vehicle electrification poses distinct challenges for urban power systems due to higher energy demands, fast-charging requirements, and the spatial concentration of freight activities. Anticipating these impacts remains a key challenge for adaptive urban infrastructure planning. This study examines freight electrification in Singapore as a predictive infrastructure challenge by integrating large-scale vehicle mobility data with charging and power system simulations. We draw on the HV operational data, comprising GPS traces from 1,360 private buses and about 2,600 heavy goods vehicles, together with the dataset of heavy-vehicle carparks in Singapore. Using observed mobility patterns, we develop synthetic mobility profiles to represent the full electric HV fleet under future electrification scenarios. These profiles are used to simulate charging demand, temporal load profiles, and potential impacts on the urban power grid. Our result suggests that charging demand can be highly concentrated in specific locations and time periods, with a strong reliance on fast charging at HV parking facilities. This concentration can create localized power demand peaks, suggesting that targeted grid upgrades or adaptive charging strategies may be required as electrification scales. In parallel, we assess emission reductions associated with different electrification levels. Our results indicate that HV electrification in Singapore offers substantial potential for emission reduction (up to ~65%), reflecting the high utilisation and regularity of HV operation. Overall, this work demonstrates how mobility-driven predictive analytics can help cities anticipate infrastructure stress points and design more responsive, data-informed strategies for the electrification of urban freight systems.

Keywords: Heavy-duty Vehicle Electrification, Predictive Infrastructure Planning, Power Grid Impact, Urban Freight Mobility

P1.09

Application of Multispectral Satellite Imagery and AI for Large-Scale Urban Tree Health Monitoring

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Urban tree populations are essential for city liveability, but their growth presents challenges for monitoring and maintenance. Singapore's One Million Tree Movement aims to increase its urban tree population to 8 million by 2030, driving the need for scalable, efficient tree health monitoring systems. Traditional inspection methods are labour-intensive and struggle to meet growing demand. This research explores integrating multispectral satellite imagery and artificial intelligence (AI) to monitor tree health at an individual level in urban environments. We combined satellite imagery, machine vision, and machine learning (ML) to develop a system for detecting and monitoring tree health. The project used Remote Tree Management Systems (RTMS) with LiDAR and Mobile Laser Scanning (MLS) to capture 3D point clouds of urban trees, aligning these with satellite imagery to delineate tree crowns. AI models, including Vision Transformers (ViT) and Multi-Layer Perceptrons (MLP), were trained with fused data to predict tree health. Ground truth data were collected through Visual Tree Assessments by Certified Arborists using the ISA Basic Tree Risk Assessment Form. These assessments validated AI predictions and enabled iterative model refinement. The model achieved 80.67% accuracy, demonstrating its ability to identify unhealthy trees. We also applied SHAP (Shapley Additive exPlanations) to ensure transparency in model decisions, showing that tree species and vegetation indices such as EPI and RGBVI were crucial for predicting tree health. This work highlights the potential of satellite-based AI systems for urban tree health monitoring, offering scalable solutions for managing large tree populations in Singapore and other tropical regions. The technology reduces operational strain, speeds up inspections, and improves urban forest management. Future work will focus on improving the accuracy and expanding the AI model to detect specific tree health issues, including insect infestations, diseases, and abiotic stress.

Keywords: Satellite Imagery, Artificial Intelligence, Tree Health Monitoring, Machine Vision, Urban Forestry, Remote Sensing

P1.10

Bridging the Divide Between AI Potential and Operational Reality in Urban Governance

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Artificial Intelligence (AI) has become central to contemporary smart city visions, promising real-time adaptive mobility systems, predictive infrastructure maintenance, and data-driven urban governance. More recently, cities have begun positioning AI as an enabler of regenerative urbanism — utilising data to support climate adaptation and long-term urban resilience. However, a significant divergence exists between theoretical capabilities ("What can be done") and the operational realities of governments ("What is actually done"). While algorithms grow increasingly sophisticated, their integration into binding urban policy and daily workflow remains sporadic, often stalling in the initial stages of what we term "pilot purgatory."

This paper investigates the structural and governance implementation barriers that prevent AI technologies from scaling beyond the literature into permanent urban planning tools. Through a comparative analysis of recent initiatives in globally recognised smart city testbeds, this research contrasts the technical specifications of proposed AI models against the regulatory and administrative frameworks available to sustain them in practice.

Our findings show that the primary obstacles to AI adoption for urban planning are not technological limitations, but institutional constraints. These include fragmented data governance, procurement rigidities, and a misalignment between dynamic algorithms and static statutory planning processes. Critically, these administrative constraints impede the deployment of urgent climate-responsive interventions.

Building on these insights, we propose an "Operational AI Readiness" framework that provides policymakers with a practical roadmap for embedding AI into regenerative urban governance — aligning administrative workflows, regulatory mechanisms, and organisational capacity with emerging algorithmic capabilities. The paper offers actionable guidance for cities seeking to move beyond pilot projects toward durable, accountable, and scalable AI-enabled planning systems that support long-term urban regeneration.

Keywords: Urban Governance, Urban Artificial Intelligence, Smart City Implementation

P1.11

"Good Enough" Low-Cost VR Trainers for Maintenance Technicians

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An immersive virtual reality (VR) trainer is expected to provide high level of realism. While VR rigs are becoming more affordable, the effort needed to develop high-fidelity VR environment remains significant. The high cost involved is a key barrier to wide adoption of VR trainers at the workplace. For industrial skill training, the cost goes beyond once-off upfront investments. This study proposes "good-enough" fidelity VR trainers as lightweight solutions to support industrial technicians to learn new maintenance tasks. Particularly for technicians sustaining urban infrastructure, they handle multiple models of similar equipment such as generators, pumps, electrical devices. Instead of pursuing costly VR simulations with high level of realism, the study investigates deliberately low-fidelity VR environments that preserve essential task affordances and procedural cues while omitting sensory details that are typical the key cost drivers to VR solution development. Besides bringing convenience and cost efficiencies by conducting training virtually, VR training tools must ultimately be pedagogically sound. The aim is to identify a "goldilocks zone" of fidelity that is just sufficient for effective procedural skills learning that translates to operational performance for technicians to pick up new maintenance skills. This study is still underway. Experiments are being conducted to gather and compare data from traditional training methods (i.e. hands-on with physical mock-ups) against training conducted using low-fidelity VR trainers to assess whether the latter can match or surpass conventional methods in speed and accuracy while not imposing excessive cognitive load on the learner. Extending these insights to sustaining urban building operations, low cost "good-enough" VR trainers can support technicians to rapidly learn to maintain a diverse variety of building-critical equipment, such as elevators, HVAC systems, backup generators, etc, effectively through repeatable practice in the VR environment without having to disrupt live systems.

Keywords: Cyber-physical, Knowledge Transfer, Training, Pedagogy

P1.12

From Km-Scale to 100m Resolution: Future Urban Heat Island of Singapore

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Singapore is a highly urbanised coastal city in deep tropics, facing increased weather and climate risks with rising temperatures and more wet and dry extremes. The latest Singapore's Third National Climate Change Study (V3) provides 2-km high-resolution climate change projections for Singapore and the broader Southeast Asian region to the end of 2100. In addition to rising temperatures, Singapore is also facing Urban Heat Island (UHI) effects, a phenomenon where urban areas experience significantly warmer temperatures than their surrounding rural areas, which is not addressed in V3. To bridge this gap, we employed uSINGV, a high-resolution urban-scale modelling version of numerical modelling system (SINGV) developed at CCRS, to further downscale the future climate projections to 100 m. uSINGV offers both increased model resolution and better representation of urban surfaces and processes through an urban canopy model. In this study, we selected both historical and future hottest days from V3 to drive 100 m uSINGV simulations. The results reveal that for future hottest days, Singapore's island wide UHI intensity is not expected to exceed that of the historical period, although near-surface temperatures will increase. The future island wide UHI intensity peaks during the night, while daytime shows a negative UHI intensity (or cool island effects). This island-wide negative UHI intensity during the day is primarily attributed to sea breezes cooling the southern coast and parts of inland Singapore, resulting in a lower island-wide average temperature compared to rural sites. This suggests that in addition to UHI intensity, we may need other measures to fully capture the complexity of future heat scenarios that Singapore will encounter.

Keywords: Future Climate, High Resolution, Urban Heat Island, uSINGV

P1.13

Advancing Singapore's Net-Zero Housing: AI-Accelerated Design Optimisation of High-Rise Residential Precincts

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Singapore's updated Nationally Determined Contribution (NDC) commits to reducing national greenhouse gas emissions to 45–50 $MtCO_2e$ by 2035, placing the decarbonisation of the built environment at the centre of climate mitigation efforts. Buildings account for over 20% of national emissions, while households consumed 8 TWh of electricity in 2024, corresponding to approximately 5–7% of grid-associated emissions. With nearly 80% of the population residing in Housing and Development Board (HDB) estates, high-rise residential districts represent a critical lever for achieving net-zero ambitions in tropical cities. Designing Net-Zero Energy (NZE) districts, however, remains a complex urban challenge that requires both exploratory capacity and strategic foresight. Design space exploration involves generating diverse configurations, evaluating performance, and navigating high-dimensional spaces shaped by regulatory, climatic, and energy constraints. In tropical contexts, NZE objectives extend beyond reducing energy demand to integrating passive strategies that enhance energy efficiency and indoor thermal comfort while maintaining high-density development. Traditional physics-based simulation workflows impose significant computational burdens, rendering exhaustive exploration impractical during early design stages. This research addresses these limitations through an AI-accelerated optimisation framework that integrates urban design, performance simulation, and surrogate modelling for precinct-scale NZE assessment of residential developments. Applied to Singapore as a proxy for tropical cities, the framework enables rapid, data-driven exploration to identify configurations capable of achieving net-zero or net-positive performance while remaining regulation-compliant. Results indicate that an optimal 2.5 GPR density enables NZE feasibility when paired with approximately 42% GFA building-integrated photovoltaic coverage and passive design strategies. Seven such optimised precincts (≈1110 residential units each) can collectively offset the operational energy demand of an eighth, demonstrating net-positive potential at the district scale. Deep-learning-based surrogates reduce simulation runtimes by 99.9% (from 39 minutes to 150 milli seconds) while maintaining a prediction error of 3.3%, enabling high-fidelity, large-scale design exploration. The study concludes that AI-enabled workflows provide a scalable and evidence-based pathway for advancing NZE housing aligned with Singapore's 2035 and 2050 climate commitments.

Keywords: Multi-objective Optimisation, Net-zero Energy Buildings, Residential Precincts, Surrogate Modelling, Transfer Learning, Urban Design

P1.14

The Role of Built Environments in Encouraging and Sustaining Older Adults' Outdoor Stay in Singapore: Using AI-Based Geospatial Modelling

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Understanding how neighbourhood built environments shape older adults' mobility is critical for evidence-based planning in ageing societies; however, existing studies often lack fine-grained measurements of behavioural patterns, especially in high-density settings. To address this gap, this study proposes an AI-based geospatial modelling framework to characterise older adults' daily mobility using high-resolution GPS trajectories. The study addresses two primary research questions: what environmental factors predict stay occurrence at a location, and what factors predict the duration of that stay. Specifically, one-day continuous GPS data were collected from 35 older adults in Singapore's public housing (HDB) neighbourhoods to capture their mobility patterns. Stay points were detected using a spatiotemporal clustering rule with a five-minute immobility threshold, distinguishing activity locations (encompassing stay occurrence and duration) from movement trajectories. Mobility data were encoded using 25-metre grid cells, each enriched with multi-source contextual features derived from GIS layers, including proximity to home, the presence of void decks, road networks, and the density of various amenities. Subsequently, XGBoost machine learning models were employed to extract latent environmental features associated with stay occurrence and duration. The ranking divergence between the two models underscores that environmental factors influencing the initial decision to stop (stay occurrence) differ significantly from those driving stay intensity (duration). Results showed that proximity (100–120m), clustered food stalls, and void decks (ground-floor semi-public spaces) are the primary predictors of both stay occurrence and duration. Furthermore, health, commercial, retail, community, and eldercare services function as destination-type facilities that sustain extended stays. The proposed framework enables scalable, micro-scale analysis of mobility–environment relationships and provides a transferable pipeline for integrating sensor data, GIS, and AI in urban analytics. Overall, this study advances data-driven approaches for adaptive neighbourhood planning and offers empirical evidence to support the design of age-supportive environments in high-density cities.

Keywords: Older Adults, Artificial Intelligence, Geospatial Modelling, Neighbourhood Built Environment, Outdoor Stay

P1.15

AI-Driven Urban Birdscaping: Revealing Hidden Habitat Patterns in Singapore's Streetscapes Through Deep Learning

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This research introduces a computational approach to understanding urban bird habitat in Singapore by training Convolutional Neural Networks (CNNs) on Google Street View imagery paired with iNaturalist bird sighting data. Unlike top-down ecological assessments, this methodology examines the urban environment at human-scale, a perspective critical for responsive cities where granular ground-level sensing captures streetscape features invisible to aerial analysis. Two ResNet50 classifiers were trained on approximately 77,000 geo-referenced iNaturalist sightings paired with Google Street View imagery: a density model across five classes (43% accuracy against a 20% chance baseline) and a species model across the eight most-observed species (27% against 12.5%). Feature maps were extracted and cross-compared across 49 convolutional layers. The analysis revealed that architectural features such as bus shelters, pedestrian bridges, and façade extensions consistently emerge as salient habitat indicators, with 64% of 100 higher-density, low-greenery images containing such structures. The research also demonstrated distinct visual signatures for different habitat conditions: overall bird density correlates with tree canopy presence, while species diversity shows affinity for multi-layered vegetation including lower bushes and lawns. Applied to Singapore's downtown core, this proof-of-concept demonstrates how AI-assisted visual analysis can systematically evaluate streetscape characteristics at scale. The pipeline is architecture-agnostic and transferable to any city with street-view coverage and citizen-science data, and can be integrated into urban dashboards, digital twins, and responsive planning systems, offering planners a complementary tool for designing bird-friendly environments from the pedestrian perspective and addressing a gap in ecological frameworks that predominantly rely on aerial imagery.

Keywords: Artificial Intelligence, Convolutional Neural Networks, Deep Learning, Street View Analysis, Urban Biodiversity, Urban Planning

P1.16

AI Computer Vision Driven Social Spatial Temporal Use and Validation

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Urban spatial use data for smaller public spaces is commonly obtained by short-term site visits and human observations. While these manual approaches offer valuable insights, being undertaken by humans they are typically limited by short durations; typically a few hours, and low samples; typically a few sites and few separate visits. Future issues are discrepancies between human observers due to qualitative subjective observations, and low quantities of objective data from manual counting. Despite the ubiquity of these methods they often fail to capture detailed usage trends, specifically over the full 24hr and weekly cycles. Thus designers need practical ways to make everyday patterns of use visible and comparable over time to support urban planning and policy.

When deployed at scale and over extended periods, large aggregated camera-based data and analytics can reveal recurring spatial and temporal patterns. The value lies in automatically identifying everyday and overlooked forms of use and supporting objective data-informed reflection on how spaces are actually inhabited across time, rather than how they are assumed to function.

The work demonstrates deploying multiple cameras in Singapore to observe small urban places over time durations of 1-12 weeks for a range of Singapore government derived high-level research questions. It presents a holistic analytical framework that combines three computer vision techniques: object detection (who's there), object tracking (where they go), and pose estimation (what they're doing). Rather than treating these as separate outputs, the methodology links them to reveal individual and group relationships between presence, movement, and engagement which aligns with how designers, planners and policy makers actually reason and make decisions about the relative use and importance of space and the urban furniture and infrastructure therein.

By interpreting presence, movement, and engagement together, it becomes possible to distinguish busy from meaningful use, identify informal practices, and recognise temporal conditions that are invisible during standard observation times but critical for specific communities. Supporting a more informed and inclusive urban design decision making.

Keywords: Camera-based Urban Analysis, Computer Vision Analytics, Spatial Use Data, Urban Analytics, Urban Sensing

P1.17

Advancing Early Design-Stage Carbon Awareness: A Parametric Building Envelope Workflow for Net-Zero Cities

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Achieving net-zero whole-life carbon emissions remains a critical challenge for the built environment, particularly as cities advance toward 2050 carbon neutrality targets. This requires early-stage design approaches that consider both operational and embodied impacts. Advances in simulation tools have enabled performance analysis during initial design phases of buildings, particularly for operational energy. More recently, parametric modelling has allowed these evaluations to be embedded within iterative workflows, connecting material choices with environmental outcomes. This integration supports more comprehensive early design exploration, where both operational energy and embodied carbon are assessed in tandem to guide low-carbon design decisions for urban environment. However, embodied carbon analysis continues to lag behind. Life cycle assessment methods are often constrained by limited data availability and remain difficult to apply during early design stages, creating a significant barrier to achieving net-zero design ambitions. This study answering those challenges by proposing a workflow focused on the building envelope to enable fast and reliable estimation of both embodied carbon and operational carbon during early-stage design. As a key driver of energy performance, the envelope plays a central role in shaping whole life carbon outcomes. Its components, including insulation layers, glazing, and material assemblies, are often adjusted throughout the design process, making them both impactful and flexible. By targeting these elements, the workflow supports exploration of design variations under uncertainty and provides meaningful data to inform low carbon strategies. It allows integrated assessment of embodied and operational impacts without requiring fully detailed specifications, enabling early feedback to guide more sustainable decisions. Initial results from three high-density residential case studies in Delhi show that performance trade-offs emerge consistently. The trade-off analysis reveals that embodied and operational carbon performance cannot be simultaneously optimised. The most balanced envelope configurations fall within EC values of 360 kilograms of carbon dioxide equivalent per square metre and OC values around 30 kilograms per square metre per year, assuming a 30-year lifespan. These Pareto-efficient regions demonstrate how design strategies that reduce operational demand may come with increased material impacts, reinforcing the importance of whole-life carbon-informed decision-making. By focusing on envelope-level variation, this approach supports more agile and targeted low-carbon design exploration during the early stages of the architectural process.

Keywords: Early-stage Design, Embodied Carbon, Design Uncertainty, Low-carbon Strategies, Operational Carbon

P1.18

Smart FM - Zero Operations

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Traditional facility management often relies on reactive maintenance and fragmented data silos, leading to operational inefficiencies in large-scale industrial estates. This research presents JTC's "Smart FM - Zero Operations" framework, powered by the Open Digital Platform (ODP), a dynamic urban operating system that acts as an autonomous system of systems capable of learning, optimising and acting in real time. The objective is to demonstrate how an integrated IT/OT infrastructure can automate routine building operations and transition facility management from reactive to predictive models through seamless consolidation of building management systems including the Smart Facility & Estate Management System (SFEMS), an advanced estate management platform. Utilising a vast network of IoT sensors and spatial intelligence capabilities, the ODP aggregates real-time telemetry from building systems[1] into a unified 3D digital twin interface, enabling advanced predictive analytics to anticipate equipment failures and optimise operational parameters. The study examines how through ODP's AI and rules-based analytics engines; adaptive built environment systems can autonomously adjust relevant systems parameters based on emergent occupancy patterns and real-time system performance data, effectively achieving "Zero Operations" to minimise manual intervention. In tandem, SFEMS leverage ODP's data to enable intelligent functionality including automated monitoring, alert generation, and tickets creation. Moreover, the ODP ecosystem encompasses robotics operations, supporting use cases including cleaning, security patrol and last-mile delivery through intelligent dispatch protocols for seamless autonomous navigation through building infrastructure such as lifts and turnstiles. Findings demonstrate this data-driven approach resulted in significant reductions in operational man-hours, substantial decreases in energy consumption, and improved equipment lifecycle management through predictive maintenance protocols. The framework maintains human oversight through an accountability layer embedded within the digital twin that alerts managers only when anomalies exceed predefined security and governance standards, ensuring operational safety whilst maximising automation efficiency. ODP's open API architecture facilitates innovation through data sharing capabilities, enabling third-party development of novel smart building solutions. In conclusion, the "Smart FM - Zero Operations" model as deployed in JTC estates illustrates how real time, evidence-based governance can transform urban facility management into a dynamic, interconnected decision-making framework, setting a new standard for intelligent, responsive urban operations.

Keywords: JTC, Open Digital Platform, Predictive Analytics, Zero Operations, Robotics, Smart Facility Management

P1.19

Bridging Urban Information Silos: A Knowledge Graph-Based Framework for Integrated Energy, Mobility, and Built Environment Governance

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Traditional city management often suffers from fragmented data landscapes, where decisions in one domain are made without considering their impacts on other systems. This paper proposes a knowledge graph-based framework that connects urban planning, building energy, mobility, and power systems data into a single, queryable digital representation to support integrated city-scale governance. By mapping relationships across these domains through shared ontological standards, the framework allows planners and modelers to query and trace information across previously siloed datasets in a single pass. The methodology is demonstrated through a multi-domain case study showing how three policy relevant domains — built environment, mobility, and energy systems — can be jointly interrogated. Specifically, the framework models how building cooling demand and electric vehicle (EV) charging loads interact to produce aggregated demand-side flexibility that can support grid stability under different disruption scenarios. For buildings, a thermal model estimates cooling energy profiles and the potential for demand curtailment as a flexibility resource. For mobility, carpark occupancy patterns are used to project EV charging loads and quantify the flexibility available through delayed charging and vehicle-to grid (V2G) strategies. Both outputs are then combined in a power systems knowledge graph to assess grid resilience. The framework is implemented using established ontologies, and demonstrates how planning, building, energy, and mobility data can be queried jointly through a shared semantic backbone. We conclude that ontology-based knowledge graphs offer a practical and robust path toward integrated urban governance, one that is scalable across domains and city contexts, and naturally extensible to emerging knowledge processing tools by grounding them in verified, traceable data.

Keywords: Demand-side Flexibility, Energy Resilience, Knowledge Graphs, Multi-domain Policymaking, Predictive Analytics, Urban Digital Twins

P1.20

From Movement to Regeneration: Evaluating the Co-Benefits of Green-Integrated Active Mobility Networks in Singapore

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Urban policy increasingly promotes active mobility not only as an alternative to motorised transport but also as a potential instrument of urban regeneration in dense tropical cities such as Singapore. However, many pedestrian and cycling corridors remain aligned with high-traffic arterials where particulate matter (PM) concentrations and thermal stress are highest, reducing the quality of movement and discouraging everyday active travel. Integrating green infrastructure into active mobility networks offers a regenerative alternative by improving microclimatic performance, reducing pollutant exposure, and enhancing thermal comfort. More fundamentally, greenery transforms mobility corridors into multifunctional urban systems that support transport, recreation, social interaction, and ecological processes.

This study develops a district-scale analytical framework to evaluate how green-integrated mobility networks contribute to environmental mitigation, social activity, and local economic performance. A mixed-methods approach combines GPS-based mobile phone data, including spatiotemporal movement patterns, pedestrian flows, social interaction proxies, and points-of-interest (POI) activity, with spatial proxies of green cover and urban form. Principal Component Analysis (PCA) is used to identify key dimensions of corridor performance, while regression analysis estimates how corridor characteristics influence activity intensity, accessibility, urban integration, and user composition.

The results show that high-performing corridors are characterised by strong accessibility, land-use integration, and environmental quality, which together support sustained active mobility, lower emissions per passenger-kilometre, and higher levels of social activity. In contrast, corridors with limited accessibility or mono-functional land use exhibit inefficient mobility patterns. The study demonstrates that corridor performance depends on the interaction between environmental quality, accessibility, and urban form, providing a data-driven framework for planning regenerative active mobility systems in high-density tropical cities.

Keywords: Urban Regeneration, Active Mobility Networks, Mobility Behaviour, Spatial Analysis, Sustainable Integrated Districts (SIDs)

P1.21

Multi-Modal AI for Global Building Stock Embodied Carbon Assessment

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Global-scale assessment of embodied carbon (EC) in building stocks is challenged by fragmented data availability, inconsistent global records, and the lack of unified modelling frameworks capable of handling uncertainty across diverse urban contexts and building typologies. This study presents a comprehensive multi-modal AI methodology that integrates Convolutional Neural Networks (CNNs), Graph Neural Networks (GNNs), and global Material Intensity (MI) databases to enable scalable and uncertainty-aware embodied carbon assessment for urban and national decarbonisation decision-making. Our study integrates multi-modal building information, imagery, spatial relationships, and archetype-based MI probability distributions from global datasets to enable consistent embodied carbon estimation across heterogeneous building stocks. Specifically, the workflow begins by integrating existing global MI databases and constructing a global MI "knowledge base" through standardized building features definitions, generation of valid archetype subsets, and probabilistic MI fitting using parametric distributions. This yields a multi-indexed MI database that supports hierarchical fallback logic, which maximises the precision of MI assignment when building prototypes with incomplete features. At the country/city level, the CNN models extract structural, material, and morphological features from satellite and street-view imagery, while the GNNs model adjacency, functional similarity, and urban relationships to propagate known attributes across a relational building graph, thereby addressing data sparsity by inferring missing building features based on contextual similarity. The fused and imputed attribute sets are matched to the most similar MI prototype in the global MI "knowledge base", ensuring that each building receives an uncertainty-aware MI distribution suitable for cross-city and policy-relevant carbon comparison. Embodied carbon for the country-wide building stock can be calculated by combining building material quantities with country-specific emission factors, with uncertainty quantified through Monte Carlo propagation of probabilistic material intensities, emission factors, and supply-chain variations. Leveraging open databases enables cross-regional comparability, while probabilistic outputs – reported as uncertainty ranges rather than deterministic values – provide a more realistic representation of embodied carbon variability, supporting robust city-scale decarbonisation planning.

Keywords: Data-efficient Modelling, Embodied Carbon, Graph Model, Material Stock, Uncertainty Quantification, Urban Sustainability

P1.22

Recovery Dynamics Influence in Urban Traffic Capacity and Resilience

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Urban traffic is a network system that can undergo regime shifts between macroscopic free-flow and congested states. It is crucial to understand and predict such transitions for urban operations and planning. Epidemic models, classifying road segments into congested and free-flow states based on vehicle speed, have been effective in describing congestion spreading at the network level. Nonetheless, they generally do not explicitly account for history-dependent behaviours in the metastable functional states, which have been increasingly observed in real urban traffic systems. Such phenomena, known as multi-metastability and hysteresis, usually indicate higher risk of functionality collapse and weaker resilience. This study aims to uncover the mechanisms responsible for this multi-metastability and hysteresis in urban traffic. Our empirical analysis of real-world traffic data from Singapore suggests that the local recovery of a congested road segment is not spontaneous. The recovery rate negatively depends on the number of congested downstream neighbours. Such dependency could be either linear or nonlinear. Simulations of this dynamical model show that the macroscopic functionality of the network can have hysteresis, only when the recovery is nonlinear. Furthermore, we find that network topology has a significant influence on the strength of hysteresis, indicating that structural properties of urban road networks modulate system-level resilience and effective traffic capacity. These results demonstrate that multiple functional metastable states and hysteresis can arise from local recovery dynamics interacting with network structure. By linking empirical observations with a mechanistic network model, this work advances theoretical understanding of the origins of history-dependent behaviour in urban traffic functionality and provides a framework for urban planners and policymakers to better assess operational limits of traffic capacity and resilience under dynamic operating conditions.

Keywords: Complex Networks, Hysteresis, Metastability, Network Dynamics, Traffic Resilience, Transportation Networks

P1.23

Underground Data Centres: Leveraging Subsurface Space for Sustainable Urban Digital Infrastructure

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Rapid growth in digital services is driving unprecedented demand for data centres in urban India, particularly in cities such as Mumbai, where surface land scarcity and high energy consumption pose significant environmental and social challenges. Globally, data centres account for approximately 1 to 1.5% of total electricity consumption, a figure projected to rise sharply alongside artificial intelligence (AI) adoption and the proliferation of connected devices. In India, the data centre market is expanding at over 15% annually, placing mounting pressure on urban land and energy systems already strained by density and climate risk. This paper explores an innovative approach: the use of underground spaces for data centre deployment, drawing on comparative insights from research and projects in Switzerland and Finland. These cases demonstrate how subsurface infrastructure can optimise energy efficiency through natural thermal regulation, which reduces cooling energy requirements by up to 30 to 40%; reduce land-use pressures; and integrate with existing urban systems whilst maintaining resilience and operational reliability. By synthesising technical, regulatory, and urban planning perspectives, the paper examines the feasibility, risks, and co-benefits of underground data centres in the Indian context. Drawing on lessons from Helsinki, Finland and Flums, Switzerland, it proposes an adaptation framework addressing geological suitability, regulatory pathways, and community considerations, offering a roadmap for cities to harness subsurface assets to support digital infrastructure sustainably. The findings aim to inform data-driven urban planning, demonstrating how cities can balance digital expansion with liveability and environmental stewardship. This research contributes to the Science of Cities discourse by linking innovative underground solutions to responsive urban management and sustainable infrastructure design.

Keywords: Data Centres, Digital Infrastructure, Energy Efficiency, Subsurface Spaces, Sustainable Urbanism, Underground Spaces

P1.24

Spatio-Thermal Resilience: Rethinking Walkability Under Urban Heat

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As tropical cities pursue car-lite mobility, pedestrian network performance can no longer be evaluated by spatial efficiency alone. Under intensifying urban heat, thermal comfort increasingly governs route choice, yet conventional planning tools such as Space Syntax assume pedestrian movement follows topologically efficient paths. This creates a growing mismatch between how cities are designed and how people actually navigate overheated urban environments. This study tests the hypothesis that extreme heat fundamentally alters pedestrian network logic by weakening the relationship between spatial configuration and pedestrian flow. Using Singapore's one-north park as a living laboratory, we develop an integrated analytical framework that couples high-resolution urban microclimate simulation with spatial network analysis and empirical movement data. Universal Thermal Climate Index (UTCI) is simulated using the Urban Multi-scale Environmental Predictor (UMEP) and calibrated with on-site sensor measurements. These thermal fields are spatially linked to network centrality measures such as Betweenness centrality and Network Quantity penalised by Distance. The resulting spatio-thermal model is validated against manual pedestrian counts collected across the full daily cycle (08:00–21:00) and during peak heat stress conditions (12:00–16:00). The results reveal a distinct thermal decoupling effect. While pedestrian movement aligns strongly with urban centrality under baseline conditions, this relationship weakens significantly during peak heat. Instead, pedestrian flows shift toward thermally favourable but topologically sub-optimal routes, forming a secondary, shade-oriented mobility network that conventional spatial analytics fail to capture. To operationalise this insight, the study introduces a Thermal Integration Index, which combines spatial accessibility with thermal performance to identify heat-vulnerable and heat-resilient links in pedestrian networks. This metric enables planners and agencies to locate where cooling interventions, shading strategies, and blue-green infrastructure would yield the greatest improvement in functional walkability. By integrating sensor-calibrated climate modelling with urban network analytics, this research demonstrates how data-driven urban operating systems can move beyond static geometry toward climate-responsive mobility planning. The framework provides a scalable method for cities to diagnose and retrofit pedestrian networks for heat resilience, supporting more liveable, equitable and climate-adaptive urban environments under global warming.

Keywords: Heat Vulnerability Index, Urban Heat Exposure, Walkability

P1.25

Housing Context, Urban Form, and Park Design in Shaping Urban Park Visitation: Mobile Big Data Evidence from Singapore

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Urban parks are distinct because they are publicly accessible, support multiple activities, and are shared by residents from both public and private housing. Understanding differences in urban park visitation and use across housing contexts is essential for planning green spaces that promote inclusive and sustainable cities, as articulated in Sustainable Development Goal 11. Singapore has a state-led housing system in which public housing plays a central role in structuring the green space system. Yet how people from different neighbourhoods, shaped by diverse environmental conditions and implicated socioeconomic backgrounds, use urban parks remains insufficiently understood. This study examines how neighbourhood spatial configuration, housing type, and park characteristics shape park visitation, and how these relationships relate to broader goals of inclusive access to urban green space and sustainable urban development. We adopt an evidence-based approach that bridges planning and design theory with observed human behaviour by combining land use and planning data, green and blue infrastructure metrics, street-level imagery, and anonymised mobile phone data. The analytical framework distinguishes between inter-park and intra-park layers to examine both access to parks and movement within them. Drawing on evidence from three urban parks in Singapore, Jurong Lake Gardens, Bishan Ang Mo Kio Park, and Punggol Waterway Park, spatiotemporal analysis shows that visitation patterns vary with visitors' housing context and their accessibility to parks. In addition, through spatial regression analysis, key features influencing intra-park movement and use are identified including both objective environmental attributes and subjective experiential indicators. Overall, the findings demonstrate that park use is closely tied to the housing system and surrounding neighbourhood structure. By providing empirical evidence on social inclusion through spatial and mobility analyses, this study underscores the value of an interdisciplinary approach and offers planning insights for integrating park design and neighbourhood planning to advance more inclusive and effective public spaces.

Keywords: Housing Context, Neighbourhood Configuration, Urban Parks, Visitation Pattern

P1.26

How Water Sensitive is My City?

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Cities experience the impacts of climate change through water-related disasters, while transitioning to sustainable and equitable water management remains crucial. Therefore, approaches that integrate water transitions with climate adaptation become essential. Various approaches exist for assessing the status of cities in water management and climate adaptation. However, they typically rely on expert judgment, without involving stakeholders. The water sensitive cities index enables cities to be actively involved and set ambitions for transitioning towards water sensitivity. As water-related challenges vary across different climatic regions and cities of different sizes, the index should be adjusted to regional and local conditions. This poster presentation responds to such a need for midsize cities in the North Sea Region. The indicators of the index and the allocation of city states were tailored to the regional conditions through a co-design process during a collaborative project and applied in seven midsize cities using a self-assessment approach. The self-assessment provides a snapshot (in 2020) which reveals strengths and weaknesses influencing the transition. Climate events or policies may have shifted since. Applying the self-assessment regularly and connecting it to local planning cycles can provide additional value. Adjusting weights of indicators can also increase the suitability to the local context.

Keywords: Climate Change Adaptation, Climate Resilience, Urban Water Management, Water Sensitive Cities, Water Transitions, Self-assessment

P1.27

Predictive Analytics for Urban Healthcare Operations: Emergency Department Arrival Forecasting in Practice

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Accurate prediction of patient arrivals is critical for effective emergency department (ED) operations, influencing staffing decisions, resource allocation, and patient flow management. Within urban environments, emergency departments function as essential components of city-wide healthcare infrastructure, where operational responsiveness directly impacts overall urban resilience and service quality. As cities increasingly adopt data-driven operating systems, predictive analytics for healthcare demand forecasting play a key role in enabling proactive and evidence-based decision-making.

Although time series forecasting methods for ED patient arrivals have been widely explored, existing studies primarily emphasise predictive accuracy. Comparatively less attention has been given to the operational considerations that determine whether such models can be reliably deployed and used in real-world urban healthcare settings. Factors such as model stability, robustness to changing demand patterns, interpretability for human decision-makers, and governance-related concerns are often underexplored despite their importance to operational adoption.

This study evaluates multiple time series forecasting approaches—including SARIMAX, Prophet, Vector Autoregression, Temporal Fusion Transformer, and TimeGPT—from an operational deployment perspective rather than accuracy alone. Using historical emergency department arrival data, we assess model performance across dimensions that are critical for integration into data-driven urban operating systems: forecasting accuracy, stability under dynamic conditions, robustness to data variability, interpretability to support human oversight, and considerations related to data privacy, AI ethics, and governance.

By positioning emergency department arrival forecasting as a decision-support capability within urban operating systems, this work demonstrates how predictive analytics can support real-time operational planning while maintaining human-centric design principles and accountability. The findings provide practical insights for healthcare practitioners, urban system designers, and policymakers, showing that effective model selection for emergency department forecasting must be guided by operational context, governance requirements, and decision-making needs, rather than predictive accuracy alone.

Keywords: Data-driven Urban Operating Systems, Emergency Department (ED) Operation, Operational Considerations, Patient Arrivals, Time Series Forecasting, Urban Healthcare Infrastructure

P1.28

Reducing the Surface Temperature but Not the Stress: A Multi-Site Micrometeorological Assessment of Heat Stress Mitigation in Tropical Schools

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As climate change intensifies heat stress, school children in tropical cities face increasing risks to development, health and well-being. Cool paints are widely promoted as a passive mitigation measure, often emphasising surface temperature reductions, yet evidence from real-world school environments remains limited. We present a multi-site micrometeorological assessment of cool paint applications across four schools in Singapore. Fifteen instrumented stations were deployed across rooftops, courtyards, greenspaces, and naturally ventilated classrooms to measure key microclimatic variables and derive human-relevant heat stress indices, including Wet Bulb Globe Temperature (WBGT) and Physiological Equivalent Temperature (PET). Where painting interventions occurred, conditions were compared across pre-/post-application periods and matched reference locations, focusing on the pedestrian-relevant layer where students learn and play. While cool paints can reduce sunlit surface temperatures, measured changes in WBGT and PET were small and inconsistent across settings, reflecting the dominant influence of the radiant environment, ventilation, and local geometry. Complementary student surveys in classrooms similarly suggest limited perceived improvement in heat stress following painting. The study underscores the need for empirical, multi-metric evaluation of heat mitigation measures in operational environments and provides a transferable sensing framework to support evidence-based decisions on heat resilience investments.

Keywords: Cool Coatings, MRT, Sensor Networks, Thermal Comfort, Urban Design, WBGT

P1.29

Associations Between the Residential Built Environment and Adolescent Sleep: A Multi-Scale Spatial Analysis

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Sleep is a critical determinant of physical, cognitive, and mental health, yet insufficient sleep is increasingly prevalent among adolescents in urban environments. While prior research has linked the built environment to various health outcomes, empirical evidence on how specific urban form characteristics influence sleep in adolescence remains limited, particularly in a dense setting like Singapore. This study examines the associations between residential built-environment characteristics and sleep duration among adolescents at age 10 (n=206), with particular attention to greenery, housing density and transport infrastructure across multiple spatial scales. We combined individual-level sleep data with high-resolution geospatial indicators of the built environment surrounding participants' homes, while sleep duration was measured using actigraphy. Built-environment exposures include tree density, non-tree vegetation, dwelling unit density and total road length, calculated within multiple circular buffers ranging from 100 m to 1000 m. Multivariable regression models shows that more non-tree vegetation coverage within 400 m and higher tree density within an 800 m residential buffer were associated with shorter sleep duration. These relationships could potentially be explained by the fact that non-tree vegetation is not so effective as trees in shielding noise, and hence not having trees sufficiently near to home could affect sleep. Living in denser residential areas, characterised by a higher number of dwelling units, was also associated with reduced sleep duration, with every 1000 more dwelling units within 300 m of the home associated with 15 less minutes of sleep. Increased total road length near the home was consistently associated with shorter sleep duration across all examined spatial scales (100-1000 m). The findings suggest that multiple dimensions of the built environment influence adolescent sleep in complex ways, and urban design strategies aimed at improving child health should consider potential trade-offs between environmental features, and sleep outcomes.

Keywords: GIS, Greenery, Sleep Duration, Urban Form, Urban Health

P1.30

Microbial First Responders: Enabling Responsive Coastal Cities After Oil Spills

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The 2024 Marine Honour oil spill along Singapore's southern coast provided a real-world test of how a large tropical coastal city can respond to sudden environmental disruption. Our study reveals that naturally occurring marine microbes function as a rapid, adaptive response system, supporting ecosystem recovery after oil contamination. By integrating field monitoring, controlled laboratory experiments, and genome-based analyses, we quantified how microbial communities shift and operate during a spill. Within days, hydrocarbon-degrading microbes became dominant, carrying genes for detoxifying and breaking down both simple and complex oil compounds. These functional capabilities persisted for over six months and even after hydrocarbons were no longer detectable, indicating the formation of an ecological "memory" that may enhance future responsiveness. Experimental data showed that oil biodegradation followed predictable first-order kinetics and exceeded abiotic loss by an order of magnitude. Degradation occurred under both oxygen-rich and oxygen-limited conditions, although rates were up to four times faster in oxygenated environments, highlighting how tidal cycles and urban shoreline dynamics influence recovery. Microbial communities dynamically switched between aerobic and anaerobic pathways, sustaining degradation across fluctuating conditions. Beyond fundamental insight, this work delivers actionable tools for responsive cities. We have developed a catalogue of oil-degrading microbial genomes and are using metabolic modelling to identify rate-limiting steps that can be targeted to accelerate clean-up both in situ and in ex situ treatment of removed oiled sand. These findings support nature-based remediation strategies, inform monitoring frameworks, and enable predictive models for faster, more effective spill response. Overall, we aim to provide research that can be integrated into urban coastal management, thus enhancing resilience, reducing recovery times, and supporting evidence-based decision-making for future environmental shocks.

Keywords: Coastal Resilience, Microbial Biodegradation, Nature-based Solutions, Oil Spill Response, Responsive Cities

P1.31

A Fluctuation-Aware Agent for Modelling Emerging Urban Intents

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In urban computing, next-Point-of-Interest (POI) recommendation systems typically rely on historical inertia to predict future movements that often treating sporadic or abrupt behavioural shifts as noise. However, urban mobility is inherently driven by dynamic intent fluctuations, where users oscillate between routine adherence and sudden desires for exploration. Neglecting these emerging intents results in systems that over-emphasise regularity, failing to support the diverse and evolving needs of city residents. To make the city system responsive to the change, this study proposes a new paradigm that focus on the dynamic change of users' intent especially under the city's complex system. Drawing on a Fluctuation-Aware Agent and employ the Detect-and-Switch framework, we introduce a probabilistic encoder that models user intent as a Gaussian distribution with dynamic variance. This variance serves as a real-time indicator of intent stability: low variance signifies adherence to routine, while high variance signals the onset of an emerging intent. The agent utilises this signal to capture the Uncertainty and Serendipity of city users. Expected findings on real-world datasets would demonstrate that our framework not only improves robustness against behavioural noise but also significantly enhances the identification of emerging intents. This research shifts the focus of urban AI from hyper-efficiency to urban vitality. By technically modelling intent fluctuation, we can algorithmically support a more vibrant, diverse, and human-centric city life.

Keywords: Mobility Uncertainty, Probabilistic Intent Modelling, Urban Mobility

P1.32

Responsive Ventilation Strategies for High-Density Housing

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High-density residential environments in rapidly urbanising regions, such as India's National Capital Region (NCR), face extreme heat and persistent air pollution that constrain conventional passive design. This study employs computational fluid dynamics (CFD) to investigate how urban form, façade design, and ventilation systems interact to shape airflow within high-rise developments. By integrating multi scale simulations—examining block-level flow, pressure differentials, and unit-level performance—the research demonstrates how airflow-informed strategies support climate-responsive housing. Results indicate that ventilation potential is primarily governed by building orientation and windward-leeward pressure differentials. While staggered massing and inter-building spacing can moderate wake interference, their influence is secondary and cannot compensate for unfavourable master-planning. At the dwelling scale, strong seasonal thresholds emerge: wind-driven cross-ventilation provides meaningful airflow during hot–dry pre-monsoon periods, whereas monsoon conditions require precise inlet–outlet coordination to remain effective. The study further evaluates two façade-based responsive strategies: evaporative misting systems and positive-pressure filtered envelopes. Under hot–dry conditions, misting achieves temperature reductions of approximately 5°C within acceptable humidity ranges, while its effectiveness declines sharply during the monsoon season. In contrast, airtight envelopes combined with mechanically assisted filtered ventilation deliver consistently healthier indoor environments, reducing CO_2 concentrations from approximately 2100 ppm to 500 ppm and PM2.5 levels from 235 µg/m³ to 0.05 µg/m³ across extreme pollution scenarios, albeit with increased operational energy demand. Rather than advocating a singular ventilation model, the findings emphasise the necessity of seasonally responsive systems that transition between natural, hybrid, and mechanical modes, enabling high-density housing to respond dynamically to climate, wind, and air quality thresholds.

Keywords: Air Pollution Mitigation, Computational Fluid Dynamics (CFD), Evaporative Cooling, Responsive Building Systems

P1.33

Tangible Digital Twins for Regenerative Cities - A Campus-Scale Model for Participatory Planning

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Transitioning towards regenerative cities requires tools that not only model complex energy flows but also engage diverse stakeholders in the decision-making process. While Urban Building Energy Modelling (UBEM) is increasingly used to support large-scale decarbonisation planning, its technical complexity often limits engagement from non-expert users in participatory planning. This study presents an interactive campus-scale platform that connects microclimate-integrated UBEM with a Tangible Digital Twin (TDT) interface, enabling intuitive exploration of building energy and sensor-derived environmental data. The platform builds on a UBEM of a 293-building university campus, developed in Rhino and simulated through ClimateStudio. A 40-station distributed campus sensor network provides localised microclimate information, including temperature, relative humidity, wind speed, and solar radiation. These sensor-derived data are integrated with baseline building energy consumption and post-intervention energy performance under selected decarbonisation scenarios. To make these data more accessible, the proposed platform combines a 3D-printed physical campus model, embedded NFC tags, and a mobile web-based interface. This "phygital" approach allows users to tap the physical model to open the interface, use the device camera to identify specific buildings, and instantly retrieve building energy and microclimate information. Beyond static visualisation, the system also allows users to interactively apply selected intervention scenarios, such as lighting dimming upgrades and cooling set-point adjustments, and visualise their energy impacts at the building level. Moving forward, the platform is intended to evolve into a "living" digital twin, allowing newly collected sensor data and updated retrofit information to be incrementally incorporated. By transforming abstract simulation outputs into an interactive, tangible, and updatable representation, the proposed approach enhances engagement, transparency, and shared understanding among researchers, designers, facility managers, and campus visitors, thereby supporting more collaborative forms of regenerative urban management.

Keywords: Interactive Decision Support, Microclimate-integrated Energy Modelling, Tangible Digital Twin, Retrofit Scenario Analysis, Smart Campus

P1.34

Governing the Intangible: An Ontology for Auditable Assumptions in Federated Energy Modelling

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Planning for decarbonisation increasingly relies on federated modelling and simulation to link cross-sector models and datasets (e.g., power systems, transport and industrial energy use) and to explore policy options via scenario runs. These runs probe alternative assumptions and constraints which are characterised by time-varying uncertainties. In practice, many assumptions that define "scenarios"—which uncertainties are considered, how they vary over time, and what is treated as fixed versus adjustable—are rarely documented in a consistent, auditable form. They persist as tacit, informally negotiated knowledge between modellers and policy makers, yet they materially determine how federated results should be interpreted and acted upon. In this sense, federated outputs are difficult to robustly govern without governing the tacit assumptions that shape them. We present an ontology-driven, governance-oriented approach that makes scenario assumptions explicit, captures uncertainty status, attaches evidence, and links each assumption to the concrete parameter and constraint settings used by every model in a federation. Implemented as an OWL ontology with modular components for scenario specification, assumption assertions, parameter assignments, and model-run events, it distinguishes policy intent expressed in natural language, model-specific parameterisations, domain-specific flexibility choices (e.g., EV charging load shifting), and structured variation of uncertain inputs. Coupled with run-level provenance and outcome metric values, the ontology yields an auditable chain from assumptions to parameters to outcomes, enabling transparent comparisons between scenarios results. Overall, this work delivers a reusable semantic foundation for interpreting federated energy-scenario results transparently. For data-driven urban policy-relevant decision support infrastructure, this semantic layer is not ancillary metadata but a core governance component: it clarifies which technological, economic, or institutional beliefs are embedded in modelling choices, separates endogenous model behaviour from modeller-imposed constraints, and augments governance and transparency in using federated analyses within a multi-stakeholder urban data-and-modelling ecosystem.

Keywords: Knowledge Engineering, Decision Support, Provenance Tracing

P1.35

Lower-cost Sensor Approach in Assessing Greenery's Impact on Thermal and Environmental Microscale Conditions across varying Greenspace Configurations

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As Singapore remains under threat of rising temperatures and high heat stress highlighted by V3, there is growing impetus to increase the area and number of cooler outdoor spaces. In the past decade, local studies have made headway in assessing outdoor thermal conditions across different land uses, greenery types, and through the use of various thermal indices. However, accounting for microscale conditions in transition across multiple varying greenspaces and land uses simultaneously remain a challenge. This study investigates the cooling potential of greenspaces of different configurations and functions on measured thermal comfort parameters through lower-cost mobile sensors. Additionally, non-thermal parameters influencing park users' experiences including PM2.5 concentrations and noise levels were measured. A multi-site deployment approach was adopted, where three greenspaces within a residential area were selected based on varying configurations and greenery characteristics. Adopting a lower-cost sensor measurement approach grants flexibility to customising measurement parameters across multiple greenspaces. This methodology can be further expanded to existing land uses or across different planning areas. Finally, deploying multiple sensors allow for simultaneous measurements to augment surveys documenting greenspace users' subjective thermal experiences.

Keywords: Urban Greenspace, Microclimate Variability, Low-cost Sensing, Mobile Measurements, Environmental Conditions

P2.01

Discovering How Digital Technologies Drive Urban Resilience Against Pandemic Crisis: A Structural Topic Modelling Approach

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Background: Although the integration of digital technologies into urban governance has accelerated, there remains a significant gap in the literature regarding their specific mechanisms and impacts on urban resilience. The COVID-19 pandemic provides a critical spatiotemporal window to observe these dynamics, as cities worldwide leveraged digital tools to navigate the crisis.

Objective: This study aims to comprehensively explore how digital technologies drive urban resilience against pandemic crises. It seeks to identify key research topics, uncover the interactions between technology and urban systems, and reveal the underlying pathways of resilience development.

Methodology: The researchers employed a structural topic modelling (STM) approach to analyse a corpus of 138 relevant articles retrieved from the Web of Science core collection. This unsupervised learning method allowed for the identification of latent thematic patterns and the quantitative assessment of topic prevalence without restrictive predefined frameworks.

Findings: The analysis identified nine distinct topics, including smart cities, digital transformation, epidemic prevention, and crisis communication. The findings indicate that digital technologies, social systems, and the pandemic environment interact to form social-environmental-technological systems (SETS). Within this framework, social systems orchestrate digital technologies to resist the pandemic, while digital tools empower social systems by enhancing risk management, emergency response, and public policy-making. This process unfolds in three phases: developing technology for response, deploying technology to resist the crisis, and leveraging digital governance for recovery and adaptation.

Conclusion: The study concludes that achieving urban resilience requires the full coordination of SETS rather than isolated technological applications. It highlights that digital technologies facilitate adaptive transformation and innovative governance models. However, the research also emphasises potential risks, such as the digital divide and privacy concerns, offering policy implications for balancing efficiency with ethics to build sustainable, resilient cities.

Keywords: COVID-19 Pandemic, Crisis, Digital Technology, Structural Topic Modelling, Urban Resilience

P2.02

From Data to Action: Real-Time CO_2 Monitoring for Indoor Air Quality Management

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Maintaining adequate ventilation is critical to reduce the accumulation of indoor airborne pollutants. CO_2 level is used as a proxy for ventilation adequacy and with the development of Internet-of-things (IOT) sensors, CO_2 monitoring can assess workplace ventilation and support operational measures among facilities managers (FM), premises operators (PO), and occupants. The study aimed to investigate: (1) the feasibility of real-time CO_2 monitoring to shape behaviour and indoor air quality (IAQ)-related actions among FM/PO and occupants, and (2) evaluate changes in knowledge, attitudes, and behaviours (KAB) over six months. CO_2 levels were monitored across 45 rooms in 13 public and private premises, with sensors positioned at breathing zone height (75-120cm from floor), placed 0.5m from occupants, avoiding windows, doors, air vents, and fans. Data were collected for one month pre-installation without in-room displays, followed by six months post-installation with real-time displays. Pre- and post-monitoring KAB surveys were conducted alongside analysis of CO_2 exceedances relative to the local standard (hourly average of 700ppm above outdoor air levels, approximately 1100 ppm total) to assess changes over time. Occupants in offices could view CO_2 readings on in-room displays, while FM/PO at all premises could access readings via monitors, dashboard or mobile application, receiving alerts when levels exceeded limits for timely mitigation. Preliminary findings showed that CO_2 monitoring demonstrated high acceptance but limited behavioural change due to structural constraints. KAB improvements varied by premises type with nursing/care homes benefiting the most, possibly supported by dedicated FM teams who found implementing mitigation measures easier, reported CO_2 monitoring as useful, and showed 100% willingness to continue the intervention. These findings align with the International Energy Agency highlighting CO_2 variability, occupant–building interactions, and practical monitoring considerations. The study demonstrates that effective CO_2 monitoring requires proactive notification systems with tailored mitigation strategies addressing varying user autonomy, alongside targeted interventions to bridge knowledge-action gaps and user group-specific advisories.

Keywords: Air-conditioned Environments, Built Infrastructure, CO_2 Monitoring, Facility Management, Ventilation

P2.03

From Proximity to Connection: Social Cohesion in Mixed-Income Precincts

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Smart urbanism is increasingly embedded in contemporary planning practice, yet its social dimensions—how residents form trust, reciprocity, and meaningful connections—remain under-examined. In Singapore, mixed-income public housing precincts are designed to foster integration and shared belonging by co-locating households from different income groups. However, physical proximity does not necessarily translate into social cohesion.

This study examines the social dynamics in two mixed-income Housing & Development Board estates, Tampines GreenEdge and West Plains @ Bukit Batok, that integrate rental and homeowner households at varying spatial scales. Using a mixed-methods design combining surveys, semi-structured interviews, community mapping, and social network analysis with 65 residents, the study investigates how spatial configurations, daily routines, and interaction patterns shape neighbourly ties. In doing so, it offers an empirically grounded account of how micro-level encounters and meso-level spatial-temporal conditions interact to influence cohesion outcomes.

Findings show that while shared spaces such as lift lobbies, void decks, and coffeeshops enable frequent everyday encounters, these interactions seldom deepen into trust or shared stewardship. Cross-tenure ties remain limited, shaped by block design, perceived social boundaries, and misaligned temporal rhythms of daily life. Nevertheless, residents consistently express a desire for closer, more reciprocal forms of neighbourly connections. These insights highlight that co-location alone is insufficient to produce social cohesion. Instead, socially-resilient precincts require what we term *social intelligence*: design and governance strategies grounded in how residents actually move, live, and connect. Rather than prescribing tested interventions, the study outlines analytically derived, multi-scalar considerations—such as designing for lingering, aligning engagement with everyday rhythms, and integrating digital and physical platforms—which can inform future implementation and evaluation using metrics of belonging, trust, and social resilience. By foregrounding lived experience and relational dynamics, this study contributes to ongoing efforts to conceptualise and assess the social dimensions of smart urbanism.

Keywords: Mixed-income Housing, Neighbourhood Interaction, Social Cohesion, Social Resilience, Urban Design and Governance

P2.04

How Cities Translate Participation into Policy: Institutional Uptake of Citizens' Assembly Recommendations in City Governance

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Cities are increasingly deploying citizens' assemblies to inform climate action and sustainable urban planning. However, there is limited evidence on how recommendations by citizens are translated into institutional decisions and policy outcomes. This paper argues that the impact of citizens' assemblies in cities is not only about their deliberative quality alone but also the institutional pathways by which recommendations are interpreted, prioritised and embedded in governance systems, with learning as a useful outcome. This paper examines the Bristol Citizens' Assembly as an in-depth qualitative case study, using semi-structured interviews with assembly members, council officers, facilitators and civil society actors and the output of assembly, council responses and implementation updates. The results show that Bristol was a good case of political ambition, assembly design and formal commitment to embed recommendations into strategic planning and policy narratives. Uptake was uneven and fragile in practice. Translation between departments was uneven, the responsibility of the delivery was diffuse and the progress was based on discretionary leadership instead of routinised processes. Besides the uptake dynamics, the Assembly generated learning effects by reshaping participants' attitudes, making institutions more aware of conditions for effective citizens' engagement and increased the perceived legitimacy of citizen participation. These learning effects were unevenly distributed and spread only weakly beyond the institution, thus having a limited impact on society as a whole. Learning was thus a parallel form of impact that accompanied moments of uptake and reflection. The paper presents Bristol as a good example of participatory innovation and a cautionary example of the limits of participation without institutional anchorage. It concludes that cities that seek to use citizens' assemblies for sustainable planning need to link participatory design with clear uptake architectures (defined decision pathways, organisational ownership and mechanisms for accountability over time).

Keywords: Citizens' Assemblies, Climate Governance, Institutional Uptake, Participatory Governance, Sustainable Urban Planning, Urban Governance

P2.05

Creating the Frontiers of the Vibe-Coded Smart City

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As cities confront rapid AI-driven transformations, a key challenge lies not in technology availability but in building human capability to adopt, govern, and innovate with AI responsibly. Since January 2025, the Singapore University of Technology and Design (SUTD) repositioned itself as the world's first Design·AI university, advancing a "Design·AI Trilingual" model that integrates design, artificial intelligence, and domain expertise to strengthen human–AI collaboration. This study examines outcomes from multiple implementations across education, industry, and public-sector contexts in terms of future of education and future of work. Using a mixed-methods approach including combining (1) results from five workshops aimed at improving professional's AI proficiency, (2) digital twin simulations for strategic organisational decision making, and (3) qualitative analysis of human–AI interaction, we evaluate how Design·AI interventions influence organisation innovation transformation and technology adoption. Findings show that participants across different sectors rapidly designed concrete AI use cases within a one-day workshop, achieving perceived productivity gains of 35–60%, reductions in prototyping time, and increased confidence in AI use. Additionally, quantitative results indicates that Design·AI workshops produced substantially statistically significant improvements in perceived ease of use of AI with a large effect size (Cohen's $d = 0.8$), lowering barriers to AI adoption at scale. Qualitative insights further reveal a shift from viewing AI as an automation tool toward treating AI as a collaborative teammate, while preserving "pockets of human centrality" in judgment, ethics, and creativity. The study concludes that Design·AI offers a human-centred, socio-technical pathway for cities to accelerate AI adoption responsibly, enhance workforce innovation capacity, and strengthen urban resilience in the AI age. The study argues that the vibe coded smart city provides a unifying framework for aligning AI-enabled learning, work, and decision-making, offering cities a practical pathway to scale AI adoption responsibly while preserving critical human-centred in ethics, creativity, and governance.

Keywords: Design·AI, Digital Twin Simulations, Human–AI Collaboration, Innovation Capacity, Smart Cities, Workshop Analytics

P2.06

Reframing Urban Sustainability: Global Expert Perspectives on Regenerative City Transitions and Pathways of Action

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In the midst of accelerating urbanisation and an escalating ecological crisis in both pace and scale, regenerative development is increasingly promoted as a promising model of urban transformation to move beyond sustainability and resilience by integratively restoring and enhancing ecological, social, and economic systems. Despite growing policy and academic interest, the concept of the "regenerative city" remains poorly defined, limiting its ability to inform concrete policies, planning decisions, and evaluative tools. To address this gap, this study employs a Delphi method to articulate a conceptual definition and core components of a regenerative city. Over a five-month span, 43 experts from the public, private, academic, and civil society sectors across 14 countries participated in a three-round online Delphi exercise. Round 1 elicited open-ended expert perspectives, followed by iterative quantitative prioritisation and qualitative refinement in Rounds 2 and 3. Through structured consensus-building, the study developed a shared definition of regenerative cities, alongside eight principles, 21 strategies, and 17 enabling conditions. Beyond areas of convergence, comparative analysis reveals sectoral differences in how strategies and enablers are prioritised, highlighting the need for evaluative frameworks that are both common and adaptable across institutional contexts. The findings emphasise that regenerative outcomes should be understood not as static attributes, but as dynamic processes unfolding across spatial and temporal scales. By advancing a consensual operational framework, this research supports policy design, cross-sector dialogue, and evidence-based urban experimentation, while laying the groundwork for indicator-based assessment frameworks that enable cities to track progress from aspirational narratives toward measurable regenerative outcomes.

Keywords: Definition, Delphi Study, Implementation Gap, Operational Framework, Regenerative City, Sustainable Urban Development

P2.07

Human-centred Operational Resilience In Urban Metro Systems: Modelling and Assessment

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Urban metro systems (UMS), as critical urban lifeline infrastructure, face increasing threats from natural disasters, technical failures, and human-induced disruptions. Enhancing operational resilience has become a paramount concern for sustainable urban development. This study proposes a "SETS-HID" (Social-Ecological-Technological Systems coupled with Human Intervention Decision) analytical framework to systematically model and assess human-centred operational resilience in UMS. Aligned with the principles of ISO 22372 (Guidelines for Infrastructure Resilience), this framework reveals the dual-driven mechanism of operational resilience formation: the internal coupling among social, ecological, and technological subsystems, and the external intervention decisions by multiple stakeholders including operators, emergency managers, and passengers. Based on multi-layer complex network theory, this study develops a digitisation mechanism that deconstructs UMS into three interdependent network layers: equipment-facility network, geographical topology network, and passenger service network. This networked modelling approach explicitly characterises the intra-layer and inter-layer interdependencies through functional, consequential, and geographical dependencies, enabling traceable propagation paths of cascading failures across heterogeneous networks. An integrated assessment method is established to assess multi-dimensional system performance, including physical resilience of the equipment-facility network, structural resilience of the geographical topology network, and service resilience of the passenger service network. Taking real UMS as a case study, stress testing is conducted under multi-hazard scenarios encompassing typhoon disasters, signal failures, and sudden large passenger flows. Results reveal differentiated impact mechanisms of various disruption types on multi-dimensional resilience, demonstrating that service resilience exhibits the most significant variation across scenarios. The proposed framework provides theoretical foundations and practical tools for resilience management in smart cities.

Keywords: ISO 22372, Integrated Assessment, Multi-hazard Scenarios, Multi-layer Complex Network

P2.08

Investigating Spatial Patterns of Transport Disadvantage using Mobile GPS Data: A Case Study of Low-Income Neighbourhoods in Ho Chi Minh City

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Many cities in ASEAN are experiencing rapid urbanisation and motorisation, resulting in a transport system heavily dependent on motorised vehicles. This model has increasingly shaped the urban form and everyday mobility of residents, where the ownership of private vehicles is prioritised, while those without access are penalised. Such characteristics have had profound implications for low-income residents, who often face increased transport disadvantage such as limited accessibility to essential services, employment opportunities, and social participation due to inadequate mobility options. As concerns over liveability, environmental sustainability, and social equity gain prominence in urban policy and planning debates, understanding and reassessing this transport model has become increasingly urgent. As such, this study aims to investigate the spatio-temporal patterns of transport disadvantage across neighbourhoods in Ho Chi Minh City and explore their relationship with their socioeconomic characteristics. Using geospatial analysis of accessibility of key destinations (e.g., their workplace, healthcare centres, schools, commercial areas, public transport nodes), alongside observable travel features such as trip distance and trip frequency, the study identified clusters of neighbourhoods where transport disadvantage is most prominent. Regression analysis revealed a statistically significant relationship between socioeconomic characteristics and transport disadvantage, which we operationalised as an accessibility-mobility gap. Housing price exhibited a strong positive association with transport disadvantage, where a one-unit increase in normalized housing price was associated with a 0.4707 increase in the transport gap value ($\beta = 0.4707$, $p < 0.001$; 95% CI: [0.427, 0.515]). This suggests that neighbourhoods with higher housing prices tend to experience substantially greater disparities in accessibility. While the model was statistically significant overall ($F = 437.9$), it explained a moderate proportion of the variation in transport disadvantage ($R^2 = 0.16$), indicating that additional factors beyond housing price also play an important role. Through revealing the spatio-temporal and socioeconomic dimensions of transport disadvantage in Ho Chi Minh City, this study aims to contribute to a deeper understanding of how transport systems can either exacerbate or mitigate urban inequality. The findings underscore the importance of reorienting transport planning and policy toward more inclusive and sustainable mobility pathways that support liveable cities and ensure equitable access for all residents amid ongoing urban transformation towards sustainable urban mobility.

Keywords: Social Exclusion, Transport Disadvantage, Vulnerable Groups

P2.09

Urban Well-Being in Post-Pandemic Ho Chi Minh City: A Data-Driven Framework for Sustainable and Resilient Urban Futures

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Rapid transformations in the structure and function of cities profoundly shape residents' well-being and quality of life. However, the COVID-19 pandemic exposed critical vulnerabilities and overlooked gaps in how urban well-being is understood and supported in the aftermath. The social upheavals brought on by the pandemic further question the changes in circumstances, experiences and expectations that underlie what it means to live well and resiliently amid simultaneous urban transformation and future uncertainties. Using a mixed-mode (online and on-site) city-wide survey in Ho Chi Minh City (HCMC), Vietnam, this study revisits how well-being is perceived and experienced in post-pandemic contexts. Applying Exploratory Factor Analysis (EFA), we developed a data-driven framework of urban well-being, comprising six dimensions: Infrastructure and Amenities, Environmental and Social Safety, Digital Competence, Support Systems, Neighbourliness, and Digital Trust. Factor scores for overall urban well-being and its six dimensions were calculated and spatially compared across five regions in HCMC: Old Town, New Town, Thu Duc City, Suburban, and Rural. Our findings reveal the material-social-digital tension shaping urban well-being, with patterns of complementarities, compensations and tensions observed across different factors in different regions. Rural areas demonstrate relative strengths in safety, support, and digital trust despite infrastructure deficits, while well-being in Old Town and New Town areas is driven by a pronounced advantage in infrastructure and amenities. Digital competence and digital trust are emerging structural conditions of urban resilience, expanding what residents can access and navigate when physical environments or infrastructure fall short. This study provides a conceptual scaffold and empirical example for identifying determinants of urban resilience and well-being that can be adapted, refined, and expanded upon to foster resilient and sustainable urban futures in HCMC and other cities across the region.

Keywords: Post-pandemic Cities, Resilient Planning, Urban Liveability

P2.10

Places for People: Integrating User Behaviour and Cognition Evidence into Architectural Design

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As our cities become increasingly complex, so do the spaces in which everyday activities occur; built environments must adapt to become more versatile, catering to different user needs and activities. Therefore, it is vital to understand the bidirectional relationship between people and spaces – how people use spaces, as well as how spatial design impacts user experience. Additionally, designers are increasingly pressed to provide 'evidence' as to how their design solutions create resilient, human-centric spaces. Therefore, we need data that sheds light on this bidirectional relationship. To tackle this, we developed a three-pillared research framework to (1) generate knowledge on person-environment relations, (2) explore how designers conceptualise end-users, and (3) build tools to help translate data into practice. In this poster, we highlight new examples of research conducted in each pillar. Projects focus on generating knowledge, and on understanding how to provide knowledge resources which improve uptake from practitioners. As examples, we present a spatial exploration eye-tracking study showing how complexity influences spatial experience. Further, we systematically map human-centric spatial analysis methods/metrics to create a taxonomy of tools that could enable more accessible, evidence-based design workflows for practitioners. And finally, to display how user data can feed back directly into design workflows, we present a study run with UNStudio, in which we used the case study site of a light rail transit station to develop a framework for embedding evidence-based design methods into practice. Overall, this body of work demonstrates that for effective feedback of research evidence into design processes, and to help generate data-informed design decisions for human-centric urban spaces, we need to converge multiple approaches for conducting behavioural and cognition research.

Keywords: Architectural Cognition, Evidence-based Design, Human-centric Design

P2.11

The Social Architecture of Climate Policy: Network Structures and Climate Strategy Uptake in Singapore

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Planning and delivering an ecologically sustainable built environment depends on how firms collaborate, not just what they can do individually. Focusing on Singapore, this study examines how professional networks shape the uptake of climate change strategies (CCS) among developers, architects, and built environment consultants (DABECs). We find that CCS participation is highly uneven. Firms cluster into a tightly connected core of high-performing actors, while many others remain more peripheral. Within this core, a small group of "integrative elites" stands out: these firms are not only well-connected and strongly engaged in green projects, but also span multiple parts of the network, linking otherwise separate clusters. This structure matters. Integrative elites play a disproportionately significant role in connecting the ecosystem and enabling the wider spread of green practices. At the same time, less connected firms face structural barriers to participating in high-performing projects. These findings suggest that accelerating CCS uptake requires more than stronger standards. It also requires targeted engagement with key bridging actors, as well as support for less-connected firms that may lack access to networks, resources, and reputational opportunities.

Keywords: Built Environment Professionals, Climate Change Strategies, Social Network Analysis, Green Mark, Collaboration, Innovation

P2.12

Adaptive Behaviours and Outdoor Thermal Comfort: A Multi-Agent System Approach Incorporating Social Archetypes

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Jan Gehl's *Life between Buildings* links successful urban life to frequent, human-scale social interaction shaped by environmental comfort. In tropical cities, excessive heat can discourage outdoor activity and social engagement. As urban temperatures rise, thermal comfort becomes a critical planning concern, as different Social Archetypes, defined by variations in vulnerability, perception, mobility, and social behaviour, adapt to heat in distinct ways. Some may cope by becoming more isolated at home, while others seek shaded or centrally cooled public spaces that sustain or enhance social interaction. Despite this behavioural diversity, widely used outdoor thermal comfort (OTC) indices, such as PET, PMV, and SET, focus on physiology and remain limited in their capacity to represent the lived experience of different social groups as they navigate diverse microclimates. These measures cannot predict how microclimate conditions influence movement, action, and social interaction across different groups. To address this gap, this study integrates urban microclimate simulations with a multi-agent system (MAS) modelling that incorporates social archetypes. Behavioural survey data is used to define archetypes of (virtual) pedestrians with distinct physiological, perceptual, and socio-behavioural attributes, enabling adaptive route choice, action, and movement within the simulation domain to capture both physiological and behavioural dimensions of thermal comfort. By modelling different behavioural responses, MAS enables the analysis of how various archetypes use, avoid, or retreat from outdoor spaces under heat stress and how social resilience can be fostered even under adverse outdoor thermal comfort conditions. This approach allows actionable insights for urban design, enabling researchers and designers to evaluate how different heat mitigation scenarios affect where people choose to walk, linger, or gather. By linking social archetypes, adaptive behaviours, and OTC, we can learn to shape outdoor spaces that are not only thermally comfortable, but socially inclusive and resilient.

Keywords: Agent-based Modelling, Urban Microclimates, Social Resilience

P2.13

Why People Dislike People in the Street: Analysing Urban Space Through Pedestrian Profiles and Situational Condition of Urban Elements

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Walkability has gained attention, yet discussions focus on mobility and movement rather than the suitability of space for specific walking purposes. Focusing on wandering, perceptions of wanderability and street elements influencing perceptions vary across user groups. The presence of people is generally considered a positive element in spaces suitable for wandering, while they can become a negative element depending on pedestrian preferences or spatial situations. Understanding contradiction is important when designing urban spaces that involve many stakeholders. To address this, we conducted an online survey in which participants compared pairs of pedestrian spaces, selected the one they would prefer to wander in, and clicked on elements in the images that explained their choice. The results show that images containing people tend to be selected as spaces people want to wander. At the same time, a contradiction emerged: in many of these images, people are also clicked as negative wandering elements. To further investigate this, it is necessary not only to identify human presence, but also to examine the situations in which it appears, and to clarify how pedestrians with different profiles perceive it differently. We analyse spatial situations in which human presence appears and is judged to make a space less desirable for wandering, even within images selected as wandering spaces. Further, we uncover the attributes of respondents who gave red flags to people appearing on the street to clarify the relationship between the pedestrian profiles and their perceptions of specific urban elements (e.g., human presence) and the general spatial situations. By accumulating knowledge on how pedestrians with specific attributes perceive wanderability differently in terms of human presence, their situational conditions, and the surrounding urban environments, this research contributes to the implementation of design guidelines for wanderable urban spaces that can respond to different targeted user groups and design objectives.

Keywords: Evidence-based Design, Image-based Survey, Spatial Dispositions, Walkability

P2.14

Assessing the Impact of Railway-Integrated Photovoltaic Noise Barriers (PVNBs) on Urban Liveability in Singapore

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The global imperative for clean energy and carbon reduction presents a unique challenge for land-scarce nations like Singapore, where conventional large-scale renewables are not viable. Concurrently, urban noise pollution, particularly for residents near above-ground rail corridors, affects liveability. This study proposes and evaluates a dual-purpose infrastructure solution: Photovoltaic Noise Barriers (PVNBs) for Singapore's railway network, framed as a responsive urban system capable of adaptive deployment within integrated energy and transport planning.

This research assesses the technical feasibility of integrating photovoltaic panels into optimised noise barrier designs. An initial acoustic analysis, supported by noise mapping, evaluated existing barrier performance. Finite element modelling then simulated various barrier profiles—specifically, vertical and T-shaped designs—with parametric variations in height and width. Results identified the T-shaped barrier as acoustically superior.

As results, subsequent energy simulation of PV panels integrated into the optimal T-shaped barrier geometry analysed variables including orientation, azimuth, and panel height. The most effective configuration was a fully panel-clad T-barrier. This integrated PVNB system has a projected annual energy yield of 157.6 GWh. This output could meet approximately 0.58% of Singapore's current electricity demand or power the equivalent of 445,323 four-room public housing flats. The study concludes that PVNBs represent a promising multifunctional strategy to advance Singapore's renewable energy targets while directly enhancing urban acoustic comfort, transforming necessary infrastructure into a scalable, adaptive source of clean power — one that can be strategically deployed across the rail network in response to evolving urban energy demands and transit expansion.

Keywords: Finite Element Model, Green Infrastructure, Noise Pollution, Renewable Energy, Urban System

P2.15

From Underutilised Viaduct Space to Living Spaces: A Participatory Model for Activating Underutilised Urban Spaces

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Public spaces have always played an important role in urban development, serving as both social and urban ecological space. However, as cities undergo rapid densification, public spaces are not always prioritised in urban planning processes, often resulting in residual or underutilised spaces. This highlights the need to understand how communities can work together to activate existing underused spaces in a climate-conscious manner. The study explores an innovative model for environmentally responsive and resilience public space design through a community-driven approach.

Viasta, short for Viaduct Fiesta, was initially a pilot project located in Changi Simei, Singapore, that tested the concept of public space participatory design. This project was initiated in 2024. Local residents, grassroot members, and stakeholders, including schools, hospitals, and community organisations were actively involved in shaping the initiative's concept and thematic direction. Rather than a short-term engagement, participation was designed as an ongoing process spanning from initial data collection, ideation, concept development, implementation, and post-event evaluation. In contrast to typical grassroot events in Singapore, this method fostered a stronger sense of community ownership over the space, its design, and long-term maintenance, extending beyond individual events to sustained stewardship of the space. The event successfully transformed the underutilised viaduct space into a green festival, showcasing community grown produce, local talents, sustainability knowledge exchange, and activities that promote active lifestyles.

Feedback was collected from the public, volunteers, and stakeholders with majority indicating that the initiative successfully activated the space, enhanced resident participation and interaction, and fostered a greater sense of community connection. However, several areas of improvement were identified, including the need to sustain momentum, deepen visitor engagement, and encourage more community-initiated activities. This feedback was taken up by the community and translated into adjustments in subsequent Viasta. Since then, the initiative has evolved into a community-led and managed, biannual event – having recently completed the fourth edition. This process underscores the potential of community-activated public spaces to not only support inclusive urban life and presents a scalable framework for the activation of underused public spaces, but also to activate and mobilise new community members, interest groups, and forms of collective engagement.

Keywords: Community-activated Public Spaces, Community-ownership and Stewardship, Participatory Design, Residual Urban Spaces, Underutilised Urban Spaces, Urban Resilience

P2.16

Comparing Urban Corridors Beyond Typology: A Reproducible GIS Workflow for Singapore

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Urban ecological corridors (UECs), including park connectors, cycling paths, natureways, parks, and forest patches, are increasingly deployed to support mobility, recreation, and biodiversity. Yet a fundamental planning question remains difficult to answer: do corridors with the same typology label function similarly? In practice, same-type corridors often sit within very different neighbourhood contexts, with varying building density, land-use, corridor width, and road fragmentation. These contextual differences strongly influence ecological performance but are rarely captured in early-stage design. A key reason is that the spatial data needed to characterise corridor contexts are fragmented, incomplete, or inconsistent in structure and resolution. This weakens early comparison and prioritisation.

This paper presents a reproducible QGIS-based workflow that integrates multi-source datasets into a consistent, comparable set of spatial indicators for UECs. The workflow demonstrated in two Singapore districts—Bukit Batok and Clementi—covering five corridor typologies in each area. We integrate agency and NParks datasets with Tree.sg and OpenStreetMap layers, and address gaps such as building height. Corridor context is summarised within a 400 m buffer, representing five-minute walk that captures the immediate surroundings influencing corridor performance. Within each catchment, we compute five indicators from widely available GIS data: built density, land-use diversity, average corridor width, maximum uninterrupted length, and road-interface intensity. A consistent 3D base model supports interpretation by visualising building heights, terrain, and corridor interruptions.

The main contribution is a transparent data-to-indicator pipeline that supports early screening and evidence-based prioritisation of segments for audits, surveys, and design review. Because the workflow relies on standard GIS data, it is readily transferable to cities facing similar data fragmentation challenges. In the next phase, the indicators will be linked to user surveys and on-site observations to test how neighbourhood context relates to corridor preference and use, enabling translation into practical planning and design guidance for UECs.

Keywords: Corridor Typologies, Multi-Source Spatial Data Integration, Planning Decision Support, QGIS Workflow, Urban Ecological Corridors

P2.17

Planet-Centric Futures: Advancing Regenerative Design for Thriving Social and Ecological Systems

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Cities are major contributors to climate change through greenhouse gas emissions, pollution, and environmental pressures associated with urbanisation, factors that affect both planetary health and citizens' well-being. Responding to these challenges requires a systems-based, regenerative approach capable not only of maintaining but also improving environmental conditions. This study investigates how Regenerative Design (RD) is emerging within Ramboll through a collaborative exploratory project with Imperial College London. The research employed a qualitative, multi-method design to analyse the challenges faced by design professionals in adopting regenerative principles, as well as the opportunities that RD introduces for transforming practice. Data collected through a participatory workshop with employees engaged in RD initiatives, along with four semi-structured interviews, were analysed using thematic analysis informed by a literature review on regenerative design, systems thinking, ecology, and transformative sustainability practices.

Findings show that regenerative design remains an evolving and context-specific concept, consistently seeking to move beyond harm mitigation toward beneficial social and ecological outcomes. Four key characteristics emerged: context as a core principle; regenerative purpose as a life-affirming and creative orientation; partnership between humans and nature; and co-evolution and adaptive processes. Participants described RD as inherently place-based, eco-centric, and focused on enabling buildings and infrastructures to become positive interventions that actively contribute to ecological regeneration and long-term well-being. The study concludes that advancing regenerative design requires a fundamental shift in worldviews, values, and understandings of human–nature relationships to support the co-evolutionary flourishing of both human and natural systems.

Keywords: Complexity, Context, Purpose, Regeneration, Systems, Wellbeing

P2.18

Revitalising Vietnamese Urban Identity through Human-Centric Community Planning

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Urbanisation in Vietnam is taking place rapidly and extensively. Many cities in Vietnam are applying Western design forms and principles, along with "smart city" concepts, to the planning, renovation, and urban design of residential areas. However, the majority of implemented solutions are predominantly technology-oriented, overlooking the urban characteristics and identities of local communities and neighbourhoods. This study proposes a human-centric community planning approach that harmoniously integrates global best practices with local cultural and urban contexts to genuinely improve the quality of the living environment in Vietnamese urban areas. Surveys indicate that over the past 10 years, the redevelopment of existing neighbourhoods and the development of new residential areas have often suffered from the mechanical application of Western principles and parameters, resulting in urban areas lacking vitality and losing their inherent urban identity. Conversely, micro-urban interventions, rooted in the traditional Vietnamese "hẻm" (alley), "phố" (street), and "khu phố" (community) culture, combined with superblock principles, yield positive results. Furthermore, prioritising urban renewal, urban upgrading, and land readjustment while limiting clearance and relocation, coupled with shared-use spatial solutions, offers superior outcomes. The study concludes that smart technology should be used not to control and manage the city, but to make residents' lives more vibrant.

Keywords: Land Readjustment, Micro-urban Interventions, Shared-use, Smart City, Superblock Principles, Urban Renewal

P2.19

Shaping Community-Centred Sustainable Cooling in a Hotter City

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It is necessary to foster sustainable cooling practices in dense tropical cities where reliance on air-conditioning carries environmental, social, and health trade-offs. Residential cooling constitutes a major share of electricity demand and anthropogenic heat emissions, with the steepest growth projected across the Global South. Addressing this is essential for public and planetary health. The Climate Resilient Citizenry project in Singapore integrates environmental, physiological, behavioural, and participatory methods to examine how residents experience everyday heat and its links to climate-related behaviours. Study 1, a physio-ethnographic investigation with 39 general-population and 15 on-going rental-flat households, revealed culturally-embedded practices that support acclimatisation like embracing perspiration and using air-conditioning adaptively. Many recognised that Singapore is getting hotter, yet heat was often normalised as a feature of daily life rather than a condition warranting proactive adaptation and mitigation. Study 2, a household population survey with 1036 residents across 416 public housing flats combined with environmental audits, showed that residents who felt more affected by heat perceived climate change as psychologically closer and engaged in more advocacy-oriented climate actions. However, this did not extend to energy-saving behaviours and they relied more heavily on air-conditioning. This reflects a behavioural insulation effect, where private cooling buffers residents from the discomfort that would otherwise motivate broader mitigation support, underscoring the tension between adaptation and long-term sustainability. Study 3, a Citizen Dialogue involving over 100 residents and experts, demonstrated motivation for change. Workshops improved knowledge and willingness to adopt sustainable cooling practices, and reduced climate disconnects although scalar disconnect remained resistant to change. Collective insights directly informed pilot interventions that are currently under development – namely a visual cooling toolkit and a renovation guide. The interventions will be tested in field experiments in the first half of 2026, with preliminary findings ready for sharing at the conference.

Keywords: Climate Resilience, Urban Tropics, Heat Adaptation, Thermal Comfort

P2.20

Pedestrian Route Choice Simulation Using Persona-Informed AI Agents

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Pedestrian route choice modelling has been widely applied in urban studies, including walkability assessment, accessibility analysis, exposure evaluation, and outdoor thermal comfort research. However, existing approaches typically assume homogeneous pedestrian behaviour and deterministic decision-making processes, thereby often failing to capture the semantic nuances and cognitive diversity inherent in human route choice. To better simulate the subjective, variable movement patterns observed in real-world pedestrian behaviour, this study proposes a persona-informed artificial intelligence (AI) pedestrian route-choice simulation framework based on large language models (LLMs). Each pedestrian persona is generated from a structured ten-question survey covering demographics, physical baseline, trip purpose, thermal sensitivity, and aesthetic preferences. An LLM converts the responses into a behavioural profile capturing identity, preferences, and decision priorities. Microclimate parameters (UTCI, wind speed, mean radiant temperature) and street-level features are simulated in Rhino with Ladybug and Eddy3D and attached to a street network of nodes and edges. At each intersection, the agent's persona, current physiological state (thermal load and fatigue), and surroundings are passed to a decision LLM, which selects the next street segment and narrates the experience. The framework was applied in Kampong Glam, Singapore, where 58 personas were simulated walking between the same origin and destination. Different personas produced markedly different routes, distances, and rest patterns, with heat sensitivity, age, and scenery preference each pulling route choice away from the shortest path. Results are delivered through PersonaWalk, an interactive platform that allows designers to inspect each persona's route, reasoning, and feedback. By treating pedestrians as cognitive AI agents capable of reasoning and preference-based decision-making, the framework enhances the behavioural realism of pedestrian simulations and supports early-stage exploration of how diverse users may experience proposed urban designs.

Keywords: Regenerative Urbanism, Large Language Models (LLMs), Cognitive Agent-based Modelling, Walkability, Outdoor Thermal Comfort, Pedestrian Dynamics

P2.21

A Human-Centred Built Environment Framework to Promote Better Mental Well-being in Singapore

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Rapid urbanisation can intensify overcrowding, environmental stressors, and living pressures, which are key factors shaping people's daily experience and mental well-being (MWB). For human-centred smart cities, a key gap is the lack of robust, interpretable evaluation frameworks that translate diverse built environment (BE) data into actionable insights on community wellbeing and social sustainability. This study develops and validates a framework for Singapore that supports evidence-based assessment of the built environment for better mental well-being. We integrate multi-source BE indicators derived from both open-source and administrative datasets with MWB measures (general MWB, depressive symptoms, stress, anxiety, emotional/behavioural, and life satisfaction), derived from 4 cohort studies in Singapore (GUSTO, S-PRESTO, SG-LEADS and MAMS). Methodologically, we combine (i) machine learning models to select features and capture interactions and thresholds, and (ii) linear mixed-effects models to provide interpretable estimates of BE–MWB relationships. Models are evaluated using cross-validation with spatial robustness checks and adjusted for sociodemographic variables. We propose a seven-domain BE framework: natural environment, environmental quality, facilities and amenities, urban mobility, urban form, housing, and perception. Models also identified important BE predictors that affect the various MWB dimensions. One of the key findings shows public transport accessibility (e.g., distance to bus stops) emerging as a salient correlate of depressive and anxiety outcomes. The resulting framework provides authorities with insights on urban planning that enhance population mental well-being and the quality of life.

Keywords: Built Environment, Human-centred Smart Cities, Linear Mixed-effects Models, Mental Well-being, Urban Analytics

P2.22

Embedding Human-Centred Metrics to Refine LLM-Based Walkability Assessments

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Multi-modal large language models (MLLMs) can score walkability assessment metrics (e.g., safety and attractiveness) using street view images (SVIs). Increasing evidence indicates that prompts embedding formal expert knowledge and incorporate evaluation metrics with specific criteria can enhance the consistency and reliability of MLLMs outputs. However, given that perceived walkability varies among individuals with different human capacity, the incorporation of relevant expert knowledge, which remains limited, has the potential to further improve MLLMs evaluation performance. To enhance MLLMs outputs to human-centred evidence for urban planning, a layer should jointly encode objective built environment metrics and subjective categories that reflect users' capacity. We extend existing built environment assessment with human-centred metrics by applying five human capacity categories that re-evaluate GPT-4o scores toward targeted user profiles, validated and reasoned by empirical data from a survey involving 674 respondents who identified "liked" and "disliked" features across 599 SVIs, paired with their age and human capacity profiles. Our objective is to explore how human capacity can refine MLLMs-based walkability assessment using SVIs. GPT-4o trials on Singapore SVIs are conducted to compare the evaluative performance of MLLMs using our developed prompts with formal expertise. The survey enable explanation on why human capacity will influence walkability. While results show that diverse human capacities potentially shift walkability preferences, our self-reported survey specifically corroborate the role of locomotor capacity in driving these perceptual variations. These findings indicate that embedding capacity metrics improves MLLMs performance in human-centred walkability assessment and supports decision-making. Future work includes developing a comprehensive walkability ontology and releasing an open-source Python package that auto-generates human-sensitive prompts for any MLLMs API to support real-time, collaborative urban planning workflows.

Keywords: Human-centred, Large Language Model, Ontology, Street View Image, User Study, Walkability Assessment

P2.23

Modelling Residential Activity Chains for Healthy Living in Singapore

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There is increasing emphasis on designing urban environments to inspire healthier living and make active lifestyle choices intuitive for everyday life. As governments expand preventive care and digital health initiatives, an important opportunity has emerged to more deeply integrate urban analytics, data science, and personalised digital health solutions to deliver targeted, place-based interventions that reflect how people live, move, and interact with cities. The limited integration across these domains presents a timely opportunity to pioneer a multidisciplinary research field with transformative potential for public health policy and planning.

This paper presents a data-driven framework for modelling the geodemographic profiles of residents in Singapore to enable personalised, place-based health promotion at scale. Drawing from a mix of administrative, health, activity and mobility data, the research develops a methodology that classifies individuals into lifestyle archetypes based on their activity and travel patterns, socio-demographic characteristics, and daily routines. The framework integrates heterogeneous datasets and leverages mobile applications to capture behavioural preferences and sensitivities across population segments, creating a data foundation for tailoring interventions to both lifestyle and neighbourhood context. We share early findings from on-going data assembly effort, as well as insights for post-research deployment that can support longitudinal updates, operational deployment, and inter-agency integration.

This research aligns with Singapore's strategic vision of preventive healthcare by pioneering an advanced digital capability to deliver personalised health promotion at scale. By generating granular insights into how the built environment shapes health behaviours across space and time, the study advances the scientific understanding of health–built environment dynamics. It further equips policymakers with actionable tools to design targeted preventive-health interventions, optimise resource allocation, and improve engagement with underserved population segments. Beyond the Singapore context, the proposed framework offers a transferable model for cities seeking to integrate urban analytics and personalised digital health platforms into next-generation preventive healthcare strategies.

Keywords: Activity-chain Modelling, Digitalisation, Geospatial, Population Segmentation, Public Health

P2.24

Responsive Social Intelligence: Urban Informality and the Reclaiming of the Transit Infrastructure at the Esplanade Underpass

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Urban underpasses are often conceived as utilitarian conduits for circulation, yet they can evolve into meaningful public spaces. In Singapore, the Esplanade Underpass exemplifies this transformation. Built in 1997 as pedestrian infrastructure, it has since been appropriated by diverse users who animate it with social, cultural, and recreational practices. Situated in a grey zone between public space and transport infrastructure, it illustrates how informal activity can generate new forms of urban commons. This study asks: How does the Esplanade Underpass illustrate third place dynamics, and how can a mixed-methods approach capture this transformation? Employing a mixed-methods framework that integrates site observations, pedestrian counts, participatory feedback, user interviews, and co-creation workshops, the research develops a multi-scalar understanding of both the material conditions and lived experiences within the underpass. The approach demonstrates how sensor-derived datasets, participatory tools, and data-informed insights can be directed toward understanding user's needs, behaviours, and aspirations rather than merely optimising infrastructure performance. Findings reveal that transient users and community groups have collectively cultivated tacit norms of respect and coexistence, transforming the underpass into an inclusive environment of co-presence. This bottom-up social intelligence illustrates how human agency is central to shaping inclusive, liveable urban spaces beyond mere occupation and fostering coexistence. Building on Lefebvre's concept of "lived space" and Oldenburg's notion of the "third place," the underpass transcends its designed function to become a socially vibrant common. Critically, the study establishes an evidence base for infrastructure renewal by clarifying which spatial conditions sustain social use, which interventions may undermine existing practices, and where targeted design actions can adapt infrastructure while preserving social value. The paper contributes a transferable framework for integrating participatory insight with operational data to support more liveable, inclusive, and socially resilient transport environments.

Keywords: Social Intelligence, Third Place, Transit Infrastructure, Urban Informality, Urban Underpasses

P2.25

The Paradox of Abundance: Divergent Definitions and Measurement Gaps in Global Smart City Indices (2019-2025)

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Since 2019, smart city indices have rapidly increased and now influence policy, investment, and city reputation. However, these indices do not measure the same concept of "smartness," as some emphasise infrastructure and connectivity while others focus on lived experience and quality of life. As a result, cities can rank very differently across indices that are often treated as comparable. This study examines how 19 global smart city indices published between 2019 and 2025 define and measure smartness. For each index, its definition, indicators, and scoring approach were reviewed. Indicators were grouped into three analytical layers: Tangible Capacity (infrastructure, connectivity, economy), Lived Experience (safety, trust, inclusion, quality of life), and Digital Governance (privacy, accountability, transparency, oversight). The indices were then compared to identify which layers were emphasised most strongly and whether any index provided balanced coverage across all three layers. The findings show that current smart city indices are not directly comparable because they measure different constructs under the same label. Most indices emphasise tangible capacity or lived experience, while digital governance is consistently under-measured. No mainstream index provides clear, weighted coverage across all three layers. These findings suggest that rankings do not only describe cities but also shape policy priorities. When benchmarking frameworks privilege visible infrastructure and service delivery, governance-related issues such as rights protection and accountability risk being overlooked. Smart city benchmarking should therefore be more transparent, more balanced, and more attentive to digital governance.

Keywords: Benchmarking, Digital Governance, Smart City, Urban Metrics, Urban Policy

P2.26

Using Social Archetypes to Strengthen Social Resilience in Singapore

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As cities evolve, governments must anticipate how diverse population groups will respond to climate stress, economic volatility, demographic change, and large-scale urban development. Effective, human-centred urban policy requires tools that help decision-makers understand social diversity and design interventions that strengthen social resilience across communities, rather than assuming a one-size-fits-all approach. This study introduces a framework for assessing social resilience using social archetypes (groups defined by shared capacities and perceptions that shape how people experience and respond to disruption). Using survey data collected in Singapore (n = 2,500), complemented by town-level surveys in contrasting urban contexts, we examined how different population groups perform in terms of social cohesion, social support, social networks, and trust in institutions under both normal conditions and potential future disruptions. Three social archetypes were identified: Optimistic Leaders, Engaged Connectors, and Reserved Individualists. Under stable conditions, Optimistic Leaders and Engaged Connectors demonstrated stronger social resilience. However, when presented with plausible future disruptions, such as climate stress, economic instability, or social change, the Reserved Individualists showed the strongest positive shifts in social resilience, suggesting the presence of latent adaptive capacity. In contrast, groups that performed well under normal conditions exhibited reductions in social cohesion and trust. These findings highlight that resilience is dynamic and context-dependent, and that population groups commonly perceived as less engaged may play a critical role during crises. This archetype-based approach offers government agencies a practical decision-support tool to anticipate social impacts, evaluate human-centred smart city initiatives, and design targeted, forward-looking interventions that enhance social resilience and inclusive participation across diverse urban communities.

Keywords: Community Wellbeing, Resilience Planning, Social Resilience, Urban Governance

P2.27

Smart City and Urban Governance in the City Of eThekwini, South Africa

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Smart City as an innovative and sustainable phenomenon is crucial in ensuring inclusive and coordinated development. The City of eThekwini with a population of 4.2 million has developed Westtown Smart City by investing an amount of R15 billion, which contributed to effective public-private partnerships in the development of mixed-land uses and green economy through environmentally friendly waste management technologies. The research objective of the study was to investigate smart city concept in enabling the provision of affordable housing solutions, energy efficiency, and green economy. Study used qualitative research approach. Data was collected through structured interviews, observations and secondary sources. Thematic analysis was used to analyse data and data is presented through narrative format. Findings revealed that the initiatives used by the City of eThekwini to promote the smart city agenda play a crucial role in enhancing green and innovative economic development, spatial resilience, and affordable housing. Findings further illustrated seamless governance pertaining to the implementation of municipal spatial vision and improved working relations between traditional and political governance structures. Challenges were identified in the form of gentrification as a negative effect of affordable housing provision that excludes urban poor. Tension exists between promoting spatial transformation and addressing spatial injustice in the provision of services aimed to empower urban poor and promote upmarket lifestyle. Implementation of a balanced spatial development approach aimed at integrating affordable housing needs of urban poor and upmarket lifestyle in the Smart City initiatives is recommended.

Keywords: Gentrification, Innovative, Resilience, Sustainability

P2.28

Creating a Data-to-Design Framework: Translating Urban Analytics into Prototypical Design Elements for Age-Friendly Communities in Singapore

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This research develops a systematic framework that connects geospatial data analytics to urban design practice, producing prototypical design elements for age-friendly public spaces in Void Decks of Singapore's Housing and Development Board (HDB) estates. The core challenge addressed is the translation gap: how to convert quantitative urban data into qualitative design decisions that result in context-appropriate, scalable interventions. The framework bridges this gap through three key innovations: (1) a GAUDT-based site identification methodology that produces "Site Archetypes" by clustering neighbourhoods based on amenity gaps and demographics; (2) Design Decision Matrices organised by five pillars of urban health that prescribe prototypical design solutions for each archetype; and (3) an integrated workflow that ensures that both community engagement and data insights directly inform design solutions, including Meanwhile Uses as a testing ground for community engagement and broader adoption. The research employs Nippon Koei Business Partner's GAUDT platform to analyse accessibility across Singapore, identifying priority sites through a transparent Priority Site Identification (PSI) scoring system. These data outputs are then systematically translated into the five pillars of urban health: Streetscape Design, Hubs of Social Interaction, Access to Healthy Food, Environmental Comfort and Preventative Healthcare to select the appropriate prototypical design solution to test within the community. The primary outcome is a validated, replicable framework that demonstrates how urban data can be operationalised into physical design elements. This framework enables community-informed, evidence-based design at scale, ensuring that prototypical interventions are deployed where they are most needed and configured to address specific local deficits.

Keywords: Age-friendly Communities, Data-driven Design, Geospatial Analytics, Modular Design, Singapore, Urban Analytics

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Translate Climate Projections to Policy with Virtual Reality

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The Third National Climate Change Study (V3) for Singapore projects changes in climate variables under three Shared Socioeconomic Pathways (SSP1-2.6, SSP2-4.5 and SSP5-8.5) and allows for a detailed understanding of the future impacts of climate change. In principle, detailed projections should enable policymakers and other stakeholders to plan for a comprehensive set of scenarios and develop effective mitigation and adaptation strategies. In reality, translating climate projections to policy remains a significant challenge for two main reasons. First, climate change projections are characterised by complex human-ecological interdependencies and a relatively high degree of uncertainty. Second, the psychological distance to climate change makes it difficult to communicate the severity of future climate impacts.

To overcome the barriers to effective translation of climate projections to policy, we ascertained the solution space for climate adaptation policies by translating projected downscaled climate impacts in Singapore into a risk assessment framework. We do this by examining extreme climate scenarios – specifically on extreme precipitation and pluvial flooding scenarios, and quantified compounding and cascading risks on the human-built environment systems. By developing a risk assessment framework, policymakers and other stakeholders will be able to navigate the complexity and uncertainty inherent in climate projections.

We further developed a Virtual Reality (VR) platform that operationalises and communicates the risk assessment framework through immersive virtual reality narratives. This approach will reduce the psychological distance to climate change and make the future impacts of climate change, along with the solution space, highly salient to policymakers and other stakeholders. We will develop proof-of-concept immersive virtual narratives to demonstrate and evaluate the effectiveness of our risk assessment and communication platform as a tool for translating climate projections to policy. This approach thus directly employs technological innovation in the form of immersive virtual reality narratives to examine climate risk perception and policy path-dependencies.

Keywords: Extreme Climate, Path Dependency, Risk Assessment, Solution Space, Virtual Reality

P2.30

The New Civic Infrastructure: Enhancing Public Trust in an Age of AI Adoption

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As cities increasingly utilise digital tools and artificial intelligence (AI) solutions, the public is being asked to trust government officials in the use of public funds, delivery of services, and policy decisions that affect people's everyday lives. Responsible AI adoption rests not only on the greater use of AI tools, but on fostering public acceptance and trust in the outcomes derived from those tools. Drawing on work from the MIT Initiative on Responsible AI (MIRA) and conversations with municipalities across the United States, I explore several measures that prepare the public to understand the issues, ask critical questions, and ultimately become comfortable with the municipal use of AI tools. To interface with individual citizens, cities can establish digital literacy programs, upskilling opportunities, and the development of civic spaces that foster public conversations on AI and digitalisation. At an organisational level, forging robust partnerships with place-based non-profits and local AI startups allow the city to be better attuned to community concerns—and in turn, spur urban solutions providers to be more responsive to public sector priorities. Finally, institutional mechanisms — including privacy safeguards, auditing and transparency norms, and participatory governance boards — can foster greater public trust in government decision-making informed by AI offerings. In combination, this collection of interfaces with individual citizens, local organisations, and the city governing structure itself, can lead to more meaningful engagement, while enhancing public trust in decision makers and the appropriate application of AI to municipal challenges.

Keywords: Artificial Intelligence, Governance, Community Engagement, Partnerships

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Future is Turquoise

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The economic, technological, social, environmental and geopolitical changes of the 21st century are creating a new world order in which connectivity, complexity and sustainability are key factors. This means a long-term, comprehensive, life-centred and interconnected system where new innovation axes and zones are emerging. Technological advances are opening up new opportunities, while the role of ancient knowledge, cultures and geography is being revalued. To understand new and complex processes, we need new kinds of maps. This paper explores global megatrends and their geographic patterns, presenting future challenges and opportunities. The study provides insights into Eurasia's long-term sustainable vision and how to manage global risks, including climate change, urbanisation and the impact of new technologies. Through the concept of 'competitiveness for viability', it presents its own academic achievement on the role of 'turquoise zones' as key spaces for innovation, creativity and sustainability.

Keywords: Geography, Geopolitics, Megatrends, Geofusion, Eurasia, Sustainability, Viability, Turquoise Zones, Innovation, World Economy

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