World Cities Summit 2024
Science of Cities Symposium

2nd June 2024

Suntec Singapore Convention & Exhibition Centre

Abstract Proceedings

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Welcome Message

Professor Lily Kong
President of Singapore Management University (SMU) and
Chairman, CLC's WCS Science of Cities Knowledge Council, Singapore

Cities now accommodate a significant proportion of the world's population, a trend projected to escalate dramatically by 2050, when nearly seven out of ten people are expected to reside in urban areas. They are hubs of learning, innovation, commerce, and productivity, of arts, creativity and vibrancy. They continue to be magnets of human population.

Yet, unprecedented challenges can exponentially impact the future of cities. Climate change, ageing populations, and a rapidly globalising workforce will increase the burden on social and fiscal support systems. The COVID-19 pandemic exposed vulnerabilities in supply chains and expedited new models of work. Cities require agility in urban governance, as they steer populations toward sustainable and equitable development in preparation for future uncertainties.

Cities are complex systems. They comprise unique, heterogenous agents – individual actors, households and families, businesses and communities, operating across multiple scales. The interactions among different agents, the feedback loops created that reinforce or challenge decisions made and actions taken, the adaption to circumstances and changing environments – all these add up to cities as complex systems. To understand how a city works, we must understand the behaviour of its inhabitants and the nature of their interactions, giving attention to how collective behaviour is manifested and changes over time.

To manage the complexity of urban ecosystems, cities must employ integrated solutions rooted in science and technology, in partnership with stakeholders, to address short-term challenges and ideate long-term solutions for resilience and adaptability.

But science isn't everything. At the hearts of cities are their inhabitants. It is imperative that urban planning, design and implementation are driven by a people-centric approach, prioritising the needs, well-being and experiences of residents. Applying science-based approaches for data-driven decision-making and innovative solutioning is fundamental to good urban practices. At the same time, it is critical to take into account individual psychologies and community cultures,

The Science of Cities will continue to transform our understanding of the urban environment. Going forward, Singapore aims to be amongst the centres developing this field globally. Our city-state's context will provide unique but also generalisable observations that contribute to a better understanding and practice of urban planning and governance. To this end, collaboration between the public, private and academic sectors is essential, drawing on respective strengths to derive useful insights and solutions.

This year's Science of Cities Symposium assembles experts and stakeholders with the goal of co-creating knowledge in Science of Climate Adaptive Cities and Science of People-Centric Cities. I am confident these collaborative efforts will facilitate the exchange of integrated urban solutions and empower us to tackle the multifaceted challenges of rejuvenating, reinventing and reimagining urban environments for a sustainable future.

Introduction

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

Date: 2nd June 2024, Sunday
Time: 1pm - 6pm
Venue: Suntec Singapore Convention & Exhibition Centre, Hall 405B (Level 4)

Convening research heads, academics, as well as city and industry leaders involved and/or keen on research developments in two panels, representing two emerging yet pertinent fields:

Panel 1: Science of Climate Adaptive Cities

Climate change and the escalating challenges posed by rising temperatures, sea-level rise, and extreme weather events, require cities to adapt the way its planned, designed and managed. The complexity of the urban ecosystem requires the cities to employ integrated solutions rooted in science, technology and partnership with stakeholders, to address both the short-term challenges and impacts of climate change, and the long-term sustainability for a resilient, adaptive city that thrive in the face of climate change. The science of climate adaptive cities continually evolves, driven by ongoing research, innovation, and collaboration among experts from diverse fields, and this session will focus on how cities are employing science to mitigate and adapt to the impacts of climate change.

Panel 2: Science of People-centric Cities

People-centric cities prioritise the well-being, needs, and experiences of its residents in its planning, design, and implementation. As the demographics, needs and preferences of people change, cities also need to adapt to maintain their relevance and efficiency to ensure high quality of life and well-being of the residents. Applying science-based approach for data-driven decision-making and innovative solutions to support the changing needs of people is fundamental to create liveable cities that are adaptable, sustainable, and conducive for the continued well-being of the people. This session will focus on how cities are employing science to develop people-centric cities.

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 would connect to WCS' main 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**
12.00-1.00pm	**Networking Lunch (By-invite only)** (at Hall 405B)
1.00–2.00pm	**Poster Exhibition** (at Exhibition Hall)
2.00–2.10pm	**Opening Remarks by Professor Lily Kong** (at Hall 405B)
Panel 1: Science of Climate Adaptive Cities	
2.10–3.50pm	**K1.1:** Urban Innovations for a Changing Climate: Insights from the Singapore-ETH Centre's Future Cities Laboratory Global *Prof Thomas Schroepfer* **K1.2:** Planning for Cities and Climate Change *Prof Barbara Norman* **O1.1:** Towards High Resolution Urban Weather and Climate Modelling for Singapore: Overview of Efforts at CCRS *Dr Song Chen* **O1.2:** Singapore's Digital Urban Climate Twin: Analysis of Measures from Island to Neighborhood Scale *Dr Kristina Orehounig* **O1.3:** The Impact of Natural Urban Terrain on Urban Wind Environment in High-density Neighborhoods using LES Turbulence Model *Prof Yuan Chao* **O1.4:** Elevating Urban Ecology: Assessing the Connectivity of Skyrise Greenery in Singapore *Dr Srilalitha Gopalakrishnan* **O1.5:** Strategies for Implementation of Green Spaces in Cities and Urban Mobility Planning *Dr Sergi Sauri* **Panel discussion** (moderated by keynote speakers)
3.50–4.10pm	Networking tea break
Panel 2: Science of People-centric Cities	
4.10–5.50pm	**K2.1:** People-centric Sustainable and Smart Cities: Technology-based, Service-focused, and Citizen-driven Cities *Prof M. Jae Moon* **K2.2:** From Designing for to Designing with *Dr Bree Trevena* **O2.1:** A 5-Minute Interlaced Township: Planning a Healthy, Regenerative, and Inclusive Town with Complete Neighbourhoods for Innovation and Resilience *Prof Heng Chye Kiang* **O2.2:** Singapore's Collaborative Modelling Approach to Support Land Use – Transport Integrated Planning *Dr Xie Litian* **O2.3:** Global Streetscapes – Benchmarking Computer Vision Models for Urban Science and Analytics *Prof Filip Biljecki* **O2.4:** Mapping Urban Belonging in Places of Flux: A Study of Lived Experience of Urban Redevelopment in Neighborhoods of Singapore *Dr Felicity H.H. Chan*

	O2.5: Architectural Cognition in Practice: A Framework for Integrating User Cognition Evidence into Architectural Design *Prof Christoph Hoelscher* **Panel discussion** (moderated by keynote speakers)

Panel 1: Science of Climate Adaptive Cities

Abstracts – Keynotes

K1.1

Urban Innovations for a Changing Climate: Insights from the Singapore-ETH Centre's Future Cities Laboratory Global

Prof Thomas SCHROEPFER
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The keynote will offer a concise look into the Singapore-ETH Centre Future Cities Laboratory's (FCL) innovative approaches to developing climate-adaptive urban spaces. It will discuss the challenges posed by climate change, particularly for urban areas, and the cutting-edge solutions that FCL has pioneered to combat these issues. The presentation will further showcase key projects that illustrate effective strategies in urban heat reduction, flood management, and energy efficiency, highlighting how these can address environmental challenges while also enhancing the quality of life for residents. Concluding with a forward-looking perspective, the keynote will emphasise the critical importance of an interdisciplinary approach in creating resilient, sustainable cities capable of thriving in the face of future climatic challenges.

K1.2

Planning for Cities and Climate Change

Prof Barbara NORMAN
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Planning for the climate change and urbanisation is now a major global and national consideration affecting cities around the world. The IPCC 6th assessment has confirmed the significant impacts indicated for urban settlements highlighting extreme heat, rainfall, drought, fire weather and coastal impacts. There are also limits to adaptation and there will be some resettlement of communities in the foreseeable future. However, while the focus must remain on reducing greenhouse gas emissions, there is much that can be done to mitigate the impacts of climate change through regulation, scenario planning, guidelines, and climate adaptation investment. Climate resilient plans will be required for all urban communities supported by appropriate capacity building to deliver climate sensitive urban design and planning. National urban policy including climate change considerations will be essential to ensuring an integrated approach to planning for cities and climate change.

Abstracts – Oral Presentations

O1.1

Towards High Resolution Urban Weather and Climate Modelling for Singapore: Overview of Effort at CCRS

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Singapore, as a coastal city-sate located within the deep tropics, experiences unique tropical weather and climate that are further complicated by its rapid urbanization. The extensive urban development, characterized by buildings and pavements, significantly modifies the surface energy balance and local atmospheric conditions. Given its high population and property density, cities like Singapore are particularly vulnerable to meteorological hazards, such as the urban heat island, flash flooding, air pollution, and sea-level rise. Understanding the dynamics between urban developments and

associated weather and climate in Singapore is crucial for sustainable planning and policy formulation. Since 2016, the Centre for Climate Research Singapore (CCRS) under Meteorological Service Singapore (MSS) has started to develop an urban modelling system known as uSINGV. This system, which is adapted from the Unified Model from the UK Met Office, is designed to investigate the impacts of urban developments on local weather and climate. This presentation will provide a comprehensive overview of research effort at CCRS, emphasizing the development of the high-resolution 100m uSINGV system. It will focus on the model development, validations with observations, key research findings, and on-going projects and collaborations. With the completion of Singapore's Third National Climate Change Study V3, this talk will also share plans to leverage the latest V3 data to further downscale the future local climate to the sub-km scale through uSINGV. This talk is deigned to inform and enhance the understanding of policymakers, urban planners, and scientists on CCRS' effort, with the aim to facilitate the evidence-based strategies for climate change mitigation and contribute to a more resilient and sustainable Singapore.

Keywords: uSINGV, Urban Meteorology, Weather and Climate Modelling, High Resolution

O1.2

Singapore´s Digital Urban Climate Twin: Analysis of Measures from Island to Neighborhood Scale

Kristina OREHOUNIG[1], J. Acero[2], H. Aydt[1], J. Ivanchev[3], I. Nevat[3], A. Sukma[1], M.L. Wong[1] and A. Zozaya[1]

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Cities are required to adapt to the changing climate to protect wellbeing and health of their population. This requires measures that guarantee a sustainable development, decrease in anthropogenic heat emissions and an improvement of outdoor thermal comfort. Measures to address these challenges are manifold and may include changes in vegetation, urban design, transport, energy, building construction and urban climatology. To identify the optimal set of measures an integrated modelling approach is needed that takes the cities infrastructure, its heat emissions, the vegetation and landuse, the behaviour of people and the prevailing climate into account. The Digital Urban Climate Twin (DUCT), developed by the Cooling Singapore 2.0 project, tries to tackle this challenge by coupling relevant models with multiple sets of input data. In this work, we demonstrate the capabilities of the DUCT by showcasing the analysis of a set of measures at island and neighbourhood scale in Singapore. Time-resolved heat emissions of buildings, traffic, industry and powerplants are modelled and further integrated as gridded anthropogenic heat emissions into a meso-scale climate model of Singapore. Vegetation and land use is represented in the form of local climate zones. The DUCT explorer, an easy-to-use interface to the DUCT, allows its user to evaluate measures in an efficient and simplified manner. With this tool-set strategic long-term development scenarios such as the Greenplan 2030 for Singapore can be analysed at island wide scale. In a next step these results can be further integrated as boundary conditions into a micro-scale climate model, to evaluate the effectiveness of measures at the local neighbourhood scale. We showcase for a set of selected measures their impact on Urban heat and Outdoor thermal comfort in Singapore.

Keywords: Digital Twin, Measures to Improve Outdoor Thermal Comfort, Urban Climate

O1.3

The Impact of Natural Urban Terrain on Urban Wind Environment in High-Density Neighborhoods using LES Turbulence Model

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Microclimatic interactions are complex, and due to limitations of computational resources, it is often neither feasible nor efficient to model and replicate the real-world built environment down to the last detail. As a result, substantial simplifications, pertinent to the model geometry, are adopted like the assumption of a flat topography. The impact of topography on wind flow has been studied at different spatial and temporal scales, yet the influence of natural urban terrain on the local wind conditions is not well understood. In this study, we investigate the impact of natural urban terrain on mean wind speed and air temperature at the pedestrian level. We conduct a numerical study using Large Eddy Simulation (LES) turbulence model for a high-density residential neighbourhood in Singapore modelled with realistic irregular terrain. We focus on two wind variations (1) low wind speed and high temperature conditions for which the atmospheric boundary layer exhibits unstable thermal stratification that is important for resilience studies and (2) annually averaged wind conditions with neutral thermal stratification that are conventionally used for urban wind studies. A statistically significant difference in mean wind speed was observed between the model with natural topography and that with homogenous flat terrain for the first scenario. More importantly, we observe a localized effect based on building density and proximity to high terrain with spatial averages as high as approximately 0.8 m/s for both the cases. This result may provide a new basis in considering urban terrain for high-fidelity simulations in climate sensitive city planning and design.

Keywords: Natural Urban Terrain, Non-isothermal condition, Numerical Simulation, Resilience

O1.4

Elevating Urban Ecology: Assessing the Connectivity of Skyrise Greenery in Singapore

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In its ambition to evolve into a "City in Nature", Singapore is committed to adding 200 hectares of skyrise greenery into its urban landscape by 2030. Beyond their recreational functions, these elevated green spaces emerge as potential ecological hubs, enriching urban ecosystems through habitat provision and biodiversity enhancement. This study presents a systematic methodology for assessing the ecological connectivity of vertically integrated urban green spaces at a neighbourhood scale, using the Wilmar building and its adjacent park within the city's one-north district as a prime example. We

use network analysis based on graph theory to study ecological network connectivity. The method represents ecological systems as networks of interconnected nodes (representing species, habitats, or ecological processes) and edges (representing interactions, such as movements or competition). By establishing each urban green space as a node and considering physical and visual accessibility as links, we employ multi-ecosystem services network analysis to evaluate connectivity measures for each node. Additionally, we utilise the Singapore Index on Cities' Biodiversity (SI) toolkit to establish quantitative metrics for assessing biodiversity scores across the study area. The results underscore the significance of vertically integrated green spaces as critical habitats for birds and pollinators, thus serving as vital components of urban ecological networks. The effectiveness of these spaces as ecological connectors is influenced by various design elements, including structured landscapes, multi-tiered planting schemes, plant diversity, the incorporation of native species, and maintaining continuity in the plant palette from ground to elevated levels. This research contributes to understanding vertical ecological connectivity within urban built environments by explaining the ecological functionality of skyrise green spaces. It offers critical insights into the current discussion about urban sustainability and biodiversity conservation, underpinning the development of cities that are both adaptive to climate change and resilient.

Keywords: Skyrise Greenery, Ecological Connectivity, Network Analysis, Biodiversity Conservation, Urban Ecosystems, Sustainable Urban Development

O1.5

Strategies for Implementation of Green Spaces in Cities and Urban Mobility Planning

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Car-oriented urban development has led to congested and polluted cities. At present, transportation is responsible for 29% of greenhouse gas emissions. In addition, wide use of private vehicles reduces the public space for other transport modes, pedestrians, and other activities. On the other hand, the effects of climate change will impact cities in multiple ways, such as extreme weather events and rising temperatures. One of the solutions to mitigate the increase in temperatures is to expand green spaces in cities. This involves reorganizing urban space by creating more space for green areas and pedestrians and reducing space for private vehicles. However, one of the main challenges in implementing and/or extending these zones is to combine them with mobility, both for passengers and freight, to keep the city running optimally. In green areas, cut-through traffic is restricted, and traffic demand is shifted towards its boundaries or other parts of the network. This creates an imbalance between the car-free inner green areas and outer areas. It will also be a challenge for public transport, especially to ensure that the quality of the bus network is not greatly affected. And the urban freight distribution will have to adapt to the new configuration of the urban space. The aim of this study is to define the implementing strategy of green areas superblocks that ensures an efficient city mobility, formulated through the generalized cost of transport including travel time, externalities, and benefits from the green areas, for a theoretical city resembling. Several scenarios for implementing green areas are evaluated in terms of traffic, public transport and urban freight

distribution. A cost-benefit analysis is carried out in order to expand on the conclusions and propose recommendations to policy and decisionmakers.

Keywords: Green Areas, Public Transportation, Traffic, Urban Mobility, Urban Freight Distribution

Panel 2: Science of People-centric Cities

Abstracts – Keynotes

K2.1

People-centric Sustainable and Smart Cities: Technology-based, Service-focused, and Citizen-driven Cities

Prof M. Jae MOON
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Since the initial concept of smart cities emerged in the 1970s, the theme has evolved significantly. Initially focused on digital technology, the emphasis has shifted towards creating cities that are human-centric, participatory, environmentally friendly, and service-oriented. Learning lessons from past experiences, the South Korean government has launched a comprehensive policy package to advance its Smart Cities Project in collaboration with local governments. This initiative aims to leverage various disruptive technologies and data, engage and empower citizens, and foster a public-private-people partnership (PPPP) for local needs to enhance quality of life, sustainability, inclusiveness, and resilience in urban areas. In the presentation, selected smart city projects will be examined to highlight core success factors and challenges to people-centric smart cities. These include the importance of citizen engagement and efficacy, the use of data and digital technologies, multistakeholder collaboration, and the evolving roles of government from commander to facilitator and curator in the design and implementation of sustainable and smart city projects.

K2.2

From Designing for to Designing with

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The success of urban places is increasingly measured by how well they support the wellbeing of our social, cultural, and natural systems. At the same time, demands on city planners have become increasingly complex as more - and more visible - economic, environmental and social trade-offs make themselves felt. Realising urban futures that actively cultivate wellbeing relies on evolving governance, planning and design processes to incorporate new perspectives and ideas. This session delves into examples of participatory policy and practice to ask, 'what's next?' for how we collectively reimagine and reinvent our civic places.

Abstracts – Oral Presentations

O2.1

A 5-Minute Interlaced Township: Planning a Healthy, Regenerative, and Inclusive Town with Complete Neighbourhoods for Innovation and Resilience

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Global cities, including Singapore, grapple with challenges such as environmental conservation, demographic shifts, technological advancements, and changing economic landscapes. To address the evolving needs of its residents, Singapore has relied on various town planning models. With emerging trends, there is a pressing need for a new planning model to enhance the living environment and ensure the relevance of its built structures. Scheduled for redevelopment between 2035 and 2050, the Paya Lebar Airbase (PLAB) and its surrounds, spanning 1870 hectares, offers a unique opportunity to devise forward-thinking and sustainable urban solutions. The overarching objective is to establish

a healthy, regenerative, and inclusive town that fosters innovation and resilience within complete neighbourhoods. Key goals encompass creating a sustainable and resilient urban environment, adapting to changing work paradigms, addressing future mobility requirements, promoting ecological equilibrium, strengthening community bonds, and preserving heritage. Systematic research, planning and design processes were executed, incorporating site analyses, structural and conceptual planning, and the development of new neighbourhood and precinct typologies. Quantitative evaluations were conducted to assess the effectiveness of proposed plans in providing adaptable, sustainable, and conducive living environments. A novel planning model was introduced, featuring a linear allocation of land uses or "bands" to enhance accessibility. On the neighbourhood and precinct scale, models emphasising pedestrian networks, activated street frontages, and social and commercial nodes were developed to promote active mobility, social interactions, and age-friendly environments. Analytical results indicate that the proposed concept enhances accessibility and creates a superior sustainable living environment, fostering self-sufficiency. These innovative concepts set the stage for the next generation of land-use planning models in Singapore, ensuring the urban landscape remains adaptable, resilient, and aligned with the evolving needs of its residents.

Keywords: Complete Neighbourhoods, New-Town Model, Spatial Planning, Sustainable Urban Solutions, Urban Resilience

O2.2

Singapore's Collaborative Modelling Approach to Support Land Use-Transport Integrated Planning

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For decades, Singapore's planning agencies have fostered a collaborative approach to integrated planning, and actively leveraged data and modelling tools. The Traffic Quantification & Transport Model (TQTM) process implemented by the Urban Redevelopment Authority (URA) and Land Transport Authority (LTA) exemplifies this synergy, supporting national strategic planning exercises like the Long-Term Plan Review and Master Plan Review; Downstream, localised transport simulations support decision-making on site-specific planning and development control parameters. To support more multi-objective, multi-scalar, and multi-team assessment, URA and LTA have embarked on a joint initiative named "SimSG". This initiative is aimed at bolstering not only technical data and modelling capabilities, but also practitioners' access to a wide suite of tools. It encompasses: 1) automation of back-end data processing to enhance efficiency and reduce potential errors; 2) cloud-based integration of land use and transport models to speed up model iterations; and 3) transformation of existing models and development of new tools to create novel capabilities for agile scenario testing. The SimSG initiative transcends the immediate benefits for URA, LTA and other government agencies, envisioning future accessibility for academic and industry professionals. This seeks to foster a robust urban planning ecosystem, reinforced by regular knowledge exchange and

collaborative innovation. This presentation delves into the data-driven and people-oriented approaches underpinning this endeavour, unpacking the multifaceted SimSG vision and initiative.

Keywords: Data-Driven Decision Making, Land Use-Transport Interactions, Planning Iterations, Transport Model

O2.3

Global Streetscapes – Benchmarking Computer Vision Models for Urban Science and Analytics

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Street view imagery (SVI) became a key data source for sensing urban environments, benefitting numerous urban research topics such as urban morphology, health, greenery, and accessibility. Billions of images around the world have been made available by commercial services such as Google Street View, and crowdsourced platforms such as Mapillary and KartaView where anyone from anywhere can upload imagery while moving. However, while the data tends to be plentiful and have high coverage and quality, and is used to derive rich insights, it remains simple and limited in metadata as characteristics such as weather, quality, and lighting condition remain unknown. This completeness challenge makes it difficult to identify images with suitable characteristics for a particular use case, potentially affecting usability and reliability. Within the Global Streetscapes dataset, a worldwide dataset of 7 million crowdsourced and free-to-use SVIs sampled from 677 cities, we manually tag 10,000 images for eight visual-contextual attributes such as panoramic status, lighting condition, view direction, weather, platform, quality, presence of glare and windshield reflections. We trained state-of-the-art deep learning models on these features and obtained accuracies of 99.9%, 96.2%, 87.4%, 75.5%, 68.3%, 79.9%, 94.1%, and 78.6%, respectively. The models and training settings are also included in the dataset with a reproducible framework to 1) sample and synthesise crowdsourced SVIs from two different platforms, 2) enrich them with rich auxiliary information to facilitate their usage and integration with external datasets, and 3) enable future updates by fetching the latest available data from the aforementioned platforms. This labelled dataset and its trained models offer, for the first time, a benchmarking dataset and baseline computer vision models for different visual-context attributes in urban science and analytics.

Keywords: Data Fusion, GeoAI, Machine Learning, Street View Imagery, Urban Analytics

O2.4

Mapping Urban Belonging in Places of Flux: A Study of Lived Experience of Urban Redevelopment in Neighborhoods of Singapore

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In the next two decades, the pace of transformation of Singapore's built environment is anticipated to accelerate and heighten as a large proportion of the neighborhoods developed in the 1970s and 1980s will undergo urban redevelopment. Everyday life in Singapore will be in a greater state of flux than ever, challenging the formation of belonging in the city - a concept associated with stability.
People-centric cities are good cities that care about the lived experience and meaning-making of urban residents, in addition to meeting their physical needs. However, therein lies a conundrum inherent in all people-centric cities that arise because redevelopment to improve urban liveability is a mixed bag of pains and joys for residents that dislocates, but also enhances our belonging in the city. Our study considers this challenge first raised by Kevin Lynch in *The Possible City (1968): How can the environment help us to live with change, and even to enjoy it?*
Using digital cognitive mapping, the presentation shares preliminary findings of a comparative study of how belonging is formed in places of flux by studying residents' lived experience in neighborhoods undergoing and facing imminent redevelopment in Singapore. Through the study, the team aims to identify the bundle of attributes of the social and spatial environments that are critical to address the urban planning tension of urban redevelopment. This research method enables access to thick qualitative data in digital form that enables robust quantitative analysis, which can yield practical insights into the types of urban planning and design parameters, critical for the development of social and physical environments that are conducive to growing belonging in cities of flux.

Keywords: Urban Change and Redevelopment, Belonging, Neighborhoods, Cognitive Mapping, Urban Planning, Singapore

O2.5

Architectural Cognition in Practice: A Framework for Integrating User Cognition Evidence into Architectural Design

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A resilient city is one in which diverse user needs are considered and carefully incorporated into architectural design choices. However, research on human-environment interactions largely happens within academic organisations, whilst architects and designers are faced with negotiating project-

specific demands. Reconciling this siloed organisation of knowledge to better integrate various kinds of expertise can lead to designs which are informed by robust scientific insights, addressing pertinent design challenges emerging in contemporary practice. What's more, there is an increasing appetite from designers themselves to know how scientific insights can be incorporated effectively into their practice. So why isn't this happening? What obstacles prevent successful integration of research into practice, and how do we overcome these? We propose a framework of integration, presenting three key streams of research with respective examples of methods and outcomes. These include: (1) Fundamental research: growing our understanding of person-environment interactions and their impact on cognition, decision making and experience, (2) Reflective research: considering how (and how well) designers conceptualise end-users, and (3) Translational research: equipping design teams with knowledge and tools to apply learnings from architectural cognition. Highlighted examples include real-world research conducted in hospitals, combining spatial and visual connectivity analyses with face-to-face interactions and behaviour mapping; researcher placements in design studios, in which interviews and observational studies explore where interventions can lie within the design process; and the development of tools that enable knowledge sharing between disciplines. Our framework applies to systems of different scales – from individual dwellings to large-scale ecosystems including ultra-mixed-use buildings, HDB estates and even complete neighbourhoods. It centres on the science of looking at human behaviour, and implements a range of behavioural, spatial, cognitive and affective mapping methodologies. We aim to better understand how environments impact users, but also, crucially, how we can take these learnings and apply them in design processes.

Keywords: Spatial Cognition, Evidence-based Design, Human-centred Design

Poster Abstracts

P1

Movable Assets Localisation Within Buildings Using Real World Coordinates

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Many robotics companies have their own proprietary systems for visualising robot movements within mapped environments and their individual systems restrict interoperability and collaboration among different robotic platforms. Recognising this as a limitation, our research aims to explore a methodology to integrate various robots onto a unified platform for collaborative visualization within a 3D digital twin. This empowers the building owner to better manage movable assets to serve its tenants and visitors, for instance, last-mile delivery of goods for tenants and ushering of visitors. This report outlines an engineering design process used for converting ROS (Robot Operating System) Robotic Map transformations from diverse movable assets into a consistent methodology for visualisation within a building space. By exploring a standardisation method to facilitate the visualization and display of robot positions on a common 3D digital twin platform, our approach harnesses Real-World Coordinates to integrate diverse robotic systems and eliminate the reliance on specialised infrastructure or sensors. Implementing this methodology at the JTC Summit building showcases the potential and feasibility of streamlining the management of multiple moveable assets within complex building environments. This serves as a blueprint for future development in JTC buildings.

Keywords: Digital Twin, Interoperability, Real-World Coordinates, Robot Operating System

P2

Effects of Tree Plantings with Varying Street Aspect Ratios on the Thermal Environment Using a Mechanistic Urban Canopy Model

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Urban tree planting is an effective strategy to reduce temperature locally and eventually mitigate Urban Heat Island. Although its cooling effects have been widely reported, understanding of coupling effects of street morphologies and tree characteristics on thermal environment is insufficient, especially in high-density cities. A parametric study is conducted to investigate effects of leaf area index (LAI = 1.0,2.0,3.0,4.0,5.0,6.0) and tree crown radius (r_{tree} = 2.0,3.4,4.4,5.0 m) on thermal environment inside streets with various aspect ratios (street height/width, H/W = 1.0–5.0). A mechanistic urban canopy model Urban Tethys-Chloris (UT&C) is selected and integrated with a new semi-empirical wind parameterization based on drag coefficients and frontal area densities of

buildings and trees. Modified UT&C is validated by a unique and controllable scaled outdoor experiment. The research outputs can be summarized as follows: (1) Calculated air temperature (T_a), wind speed (V), and thermal comfort indices (Mean Radiant Temperature (T_{mrt}) and Universal Thermal Climate Index (UTCI)) are in good agreement with results from scaled outdoor experiments, while slight overestimation of relative humidity (RH) occurs in tree cases; (2) Increasing LAI and r_{tree} both bring stronger cooling effects by up to 20.2 ℃ (T_{mrt}) and 4.0 ℃ (UTCI); (3) Narrower streets weaken trees' cooling effects and increasing LAI and r_{tree} could be less efficient for higher H/W than lower H/W; (4) LAI = 4.0 and r_{tree} = 5.0 m are optimal for wide streets (H/W = 1.0–3.0) to provide maximum UTCI cooling (about 4.0 ℃), while LAI = 4.0 and r_{tree} = 3.4 m are suggested for narrow streets (H/W = 3.0–5.0). Our study provides useful information on evidence-based urban tree selection strategies for urban planning and design.

Keywords: Pedestrian Thermal Comfort, Scaled Outdoor Experiment, Street Aspect Ratio, Urban Canopy Model, Urban Vegetation

P3

Architectural Cognition in Practice: A Framework for Integrating User Cognition Evidence into Architectural Design

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A resilient city is one in which diverse user needs are considered and carefully incorporated into architectural design choices. However, research on human-environment interactions largely happens within academic organisations, whilst architects and designers are faced with negotiating project-specific demands. Reconciling this siloed organisation of knowledge to better integrate various kinds of expertise can lead to designs which are informed by robust scientific insights, addressing pertinent design challenges emerging in contemporary practice. What's more, there is an increasing appetite from designers themselves to know how scientific insights can be incorporated effectively into their practice. So why isn't this happening? What obstacles prevent successful integration of research into practice, and how do we overcome these? We propose a framework of integration, presenting three key streams of research with respective examples of methods and outcomes. These include: (1) Fundamental research: growing our understanding of person-environment interactions and their impact on cognition, decision making and experience, (2) Reflective research: considering how (and how well) designers conceptualise end-users, and (3) Translational research: equipping design teams with knowledge and tools to apply learnings from architectural cognition. Highlighted examples include real-world research conducted in hospitals, combining spatial and visual connectivity analyses with face-to-face interactions and behaviour mapping; researcher placements in design studios, in which interviews and observational studies explore where interventions can lie within the design process; and the development of tools that enable knowledge sharing between disciplines. Our framework applies to systems of different scales – from individual dwellings to large-scale ecosystems including ultra-mixed-use buildings, HDB estates and even complete neighbourhoods. It centres on

the science of looking at human behaviour, and implements a range of behavioural, spatial, cognitive and affective mapping methodologies. We aim to better understand how environments impact users, but also, crucially, how we can take these learnings and apply them in design processes.

Keywords: Architecture, Cognition, Design

P4

Mapping Urban Spatial Resilience: First Steps Towards Spatially Adaptable Cities

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Current urban planning and design approaches often struggle to address the rapidly changing, increasingly complex, and uncertain environments that cities must navigate. In contrast, urban resilience is a promising approach for planning and design as it embraces uncertainty and encourages planning with and for change. Although urban resilience is gaining acceptance in urban discourse, there is still limited understanding of how the physical form of cities affects their capacity to adapt to changing circumstances and, consequently, their resilience. This presentation provides a synoptic overview of the results of a study that integrated the disciplines of urban morphology and urban resilience. By leveraging urban science to develop a novel approach for assessing the spatial adaptive potential of cities and identifying the urban forms and qualities that promote spatial resilience. To illustrate the application of the approach, the case study of Manhattan is showcased. In the study area, the relative multi-scale spatial adaptive potential for every location (land parcel) was assessed. The key findings of the study reveal that variations in the size, shape, and configuration of urban elements significantly impact spatial adaptive potential. Additionally, the relative location within the broader urban context plays an important role in its adaptive potential. Based on these findings, the study presents spatial resilience urban design principles to guide the development and transformation of cities towards greater resilience.

Keywords: Urban Resilience, Spatial Resilience, Urban Form, Urban Morphology, Urban Science

P5

Complexity Science in Policymaking: Why the Promise Falls Short

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As our social and technological systems become increasingly interwoven, their complexity poses challenges for traditional planning and policymaking approaches, particularly during times of change or crisis. Complexity science and systems thinking offer alternative ways of thinking and provide promising solutions. Yet, after nearly 80 years, their practical application remains limited or confined specialised fields or remain in the domain of analysis instead of providing suggestions for solutions to

problems. To understand why complexity science remains underutilised in policymaking, we conducted a scoping review. We focus our attention on the literature at the intersection of policy and complexity, specifically seeking to uncover the barriers limiting the adoption of complexity science. The results indicated that technical issues were among the most common aspects hampering the use of complexity-based approaches. These issues include, for example, difficulties in modelling complex systems (including model validation and calibration) and data (availability, quality, and detail). Beyond the technical issues, softer issues were also identified as critical factors. For example, complexity informed approaches, such as agent-based modelling, tend to be too focused on methodology and less on developing or testing theory. Additional notable issues include challenges associated with management and institutions, limited trust in the results, prediction and utility of the tools and methods rooted in complexity; limited inter-disciplinary work; and a limited understanding of complexity science by policymakers.

Keywords: Challenges, Complexity Science, Complexity Theory, Policymaking, Public Policy, Systems Thinking

P6

Physics Aware Digital Twins as Reliable, Responsible Tools to Predict and Manage Disruptions in Urban Complex Systems

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Intelligent modelling technologies such as digital twins can enhance community-centric planning by simulating urban environments and developing predictive scenarios in response to critical and uncertain situations, allowing aided or even automated real-time decision-making.
While traditional data-based AI techniques can be considered to enable the process, they still entail a number of limitations, such as the need of large amount of very specific and difficult-to-access data, massive computing resources, and questionable, sometimes risky output decisions in a few specific situations, thus lacking ethical considerations in decision-making affecting humans.

The Hybrid Artificial Intelligence (HAI) approach aims to address these gaps. It combines AI's strengths of collecting and analysing big data across systems on an accessible online platform, with the pairing of physics-informed and physic-augmented approaches to allow for updating the knowledge. Technically, a Hybrid Twin model of the ignorance (gap between knowledge-based prediction and the experimental observations) is constructed, and models are reduced by applying advanced parametric regressions techniques. This results in faster real-time diagnosis, prognosis and decision-making, using less data (frugality) yet with better accuracy in predictions, it remains almost explainable, and minimizes the ecological footprint (sustainability). By enabling human-driven updating of knowledge and security certifications, it also enables a human centric approach where the privacy of citizens is respected.

Through HAI, different technological functionalities can be elaborated and, subsequently, closely combined for constituting the complex system of systems emulating the city functioning within its environment. This is applied to a number of case-based solutions for critical urban systems, where environmental maps (wind, pollution, temperature etc.), digital energy footprint, and smart sensing of large critical civil and industrial infrastructures are assimilated to inform efficient maintenance, optimize energy distribution, and enhance crisis and emergency management.
By accounting for multiple aspects of planning and evolving information in today's VUCA environment, these methodologies can become reliable, helpful tools to foster the planning of future urban system improvements.

Keywords: Critical Urban Systems, Decision-making, Hybrid Twins, Human-centred AI, Hybrid Artificial Intelligence, Predictive Intelligent Modelling

P7

Strategies for Implementation of Green Spaces in Cities and Urban Mobility Planning

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Car-oriented urban development has led to congested and polluted cities. At present, transportation is responsible for 29% of greenhouse gas emissions. In addition, wide use of private vehicles reduces the public space for other transport modes, pedestrians and other activities. On the other hand, the effects of climate change will impact cities in multiple ways, such as extreme weather events and rising temperatures. One of the solutions to mitigate the increase in temperatures is to expand green spaces in cities. This involves reorganizing urban space by creating more space for green areas and pedestrians and reducing space for private vehicles. However, one of the main challenges in implementing and/or extending these zones is to combine them with mobility, both for passengers and freight, to keep the city running optimally. In green areas, cut-through traffic is restricted, and traffic demand is shifted towards its boundaries or other parts of the network. This creates an imbalance between the car-free inner green areas and outer areas. It will also be a challenge for public transport, especially to ensure that the quality of the bus network is not greatly affected. And the urban freight distribution will have to adapt to the new configuration of the urban space. The aim of this study is to define the implementing strategy of green areas superblocks that ensures an efficient city mobility, formulated through the generalized cost of transport including travel time, externalities, and benefits from the green areas, for a theoretical city resembling. Several scenarios for implementing green areas are evaluated in terms of traffic, public transport and urban freight distribution. A cost-benefit analysis is carried out in order to expand on the conclusions and propose recommendations to policy and decisionmakers.

Keywords: Green Areas, Public Transportation, Traffic, Urban Mobility, Urban Freight Distribution

P8

Mapping Urban Belonging in Places of Flux: A Study of Lived Experience of Urban Redevelopment in Neighborhoods of Singapore

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In the next two decades, the pace of transformation of Singapore's built environment is anticipated to accelerate and heighten as a large proportion of the neighborhoods developed in the 1970s and 1980s will undergo urban redevelopment. Everyday life in Singapore will be in a greater state of flux than ever, challenging the formation of belonging in the city - a concept associated with stability.

People-centric cities are good cities that care about the lived experience and meaning-making of urban residents, in addition to meeting their physical needs. However, therein lies a conundrum inherent in all people-centric cities that arise because redevelopment to improve urban liveability is a mixed bag of pains and joys for residents that dislocates, but also enhances our belonging in the city. Our study considers this challenge first raised by Kevin Lynch in *The Possible City (1968): How can the environment help us to live with change, and even to enjoy it?*

Using digital cognitive mapping, the presentation shares preliminary findings of a comparative study of how belonging is formed in places of flux by studying residents' lived experience in neighborhoods undergoing and facing imminent redevelopment in Singapore. Through the study, the team aims to identify the bundle of attributes of the social and spatial environments that are critical to address the urban planning tension of urban redevelopment. This research method enables access to thick qualitative data in digital form that enables robust quantitative analysis, which can yield practical insights into the types of urban planning and design parameters, critical for the development of social and physical environments that are conducive to growing belonging in cities of flux.

Keywords: Urban Change and Redevelopment, Belonging, Neighbourhoods, Cognitive Mapping, Urban Planning, Singapore

P9

A 5-Minute Interlaced Township: Planning A Healthy, Regenerative, And Inclusive Town with Complete Neighbourhoods for Innovation and Resilience

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Global cities, including Singapore, grapple with challenges such as environmental conservation, demographic shifts, technological advancements, and changing economic landscapes. To address the evolving needs of its residents, Singapore has relied on various town planning models. With emerging

trends, there is a pressing need for a new planning model to enhance the living environment and ensure the relevance of its built structures. Scheduled for redevelopment between 2035 and 2050, the Paya Lebar Airbase (PLAB) and its surrounds, spanning 1870 hectares, offers a unique opportunity to devise forward-thinking and sustainable urban solutions. The overarching objective is to establish a healthy, regenerative, and inclusive town that fosters innovation and resilience within complete neighbourhoods. Key goals encompass creating a sustainable and resilient urban environment, adapting to changing work paradigms, addressing future mobility requirements, promoting ecological equilibrium, strengthening community bonds, and preserving heritage. Systematic research, planning and design processes were executed, incorporating site analyses, structural and conceptual planning, and the development of new neighbourhood and precinct typologies. Quantitative evaluations were conducted to assess the effectiveness of proposed plans in providing adaptable, sustainable, and conducive living environments. A novel planning model was introduced, featuring a linear allocation of land uses or "bands" to enhance accessibility. On the neighbourhood and precinct scale, models emphasising pedestrian networks, activated street frontages, and social and commercial nodes were developed to promote active mobility, social interactions, and age-friendly environments. Analytical results indicate that the proposed concept enhances accessibility and creates a superior sustainable living environment, fostering self-sufficiency. These innovative concepts set the stage for the next generation of land-use planning models in Singapore, ensuring the urban landscape remains adaptable, resilient, and aligned with the evolving needs of its residents.

Keywords: Complete Neighbourhoods, New Town Model, Spatial Planning, Sustainable Urban Solutions, Urban Resilience

P10

Integrating Solar Photovoltaics and EVs to Decarbonize Singapore for Climate Mitigation

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Integrating solar photovoltaics (PV) and electric vehicles (EVs) is crucial in addressing climate change by decarbonizing the energy grid and transportation sector. While solar PV advances clean energy generation, its massive deployment could induce grid stability challenges, notably the 'duck curve' and overloading issue. EVs, particularly with vehicle-to-grid (V2G) technology, offer a resilient solution by effectively utilizing PV energy and bolstering grid stability. This study explores the potential of using EVs to assist the deployment of PVs and support the power grid operation in the Singapore context. We leverage GPS-based mobile data to analyse urban mobility and forecast EV charging demands at high spatial-temporal resolution. Through optimizing the charging and discharging schedule, our results have shown that both the system and local load profiles can be greatly stabilized, and the peak load could be substantially reduced. The results suggest that EVs can significantly contribute to a smoother renewable energy transition and mitigate emissions in Singapore. This research contributes

to the ongoing discourse on a synergistic urban planning paradigm, offering strategies pivotal for climate-focused policymakers, energy, and transport sectors.

Keywords: Electric Vehicles, Grid Stability, Solar Photovoltaics, Urban Decarbonization, Vehicle-to-Grid (V2G), Climate Mitigation

P11

Natural Ventilation in Tropical Climate: A Case Study of a Heritage Building with Site Measurements

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Natural ventilation is a passive strategy to regulate indoor air quality and temperature. Although it is challenging to adopt natural ventilation in hot and humid climates due to high outdoor air temperature and humidity, some buildings in Singapore have shown that it is possible to partially or fully adopt natural ventilation. Most of these buildings are newly-designed or retrofit campus buildings in institutes of higher learning. This study aims to extend the application of natural ventilation to heritage buildings by collecting a baseline measurement in an existing heritage building in Singapore. The Architectural Conservation Laboratory (ArClab) NUS, located at 141 Neil Road, is chosen as the study site as it is a living lab that resembles the typical heritage building typology in Singapore. The indoor temperature distribution in the living room on the ground floor is measured for three days under naturally ventilated conditions. A weather station is deployed to collect the outdoor weather parameters and 11 HOBO loggers are used to measure the indoor temperatures. The measurements show that the indoor temperature trend follows that of the outdoor temperature, with peak temperatures in the afternoon and lowest temperatures in early mornings. The indoor temperature can be up to 4 °C lower than the outdoor temperature during daytime. During nighttime, the indoor temperature is almost the same as the outdoor temperature. During the coldest time of the day, the temperature near the two windows is lower than the rest of the room, while during the hottest time, it is higher. The field measurement data will be used in subsequent research to validate computational models of ArClab NUS and derive feasible plans for energy saving by adopting natural ventilation.

Keywords: Heritage Buildings, Natural Ventilation, Site Measurement, Tropical Climate

P12

Advancing Human-Centered Urban Planning: Incorporating Human Perception in Digital Twins for Sustainable City Development

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Urban digital twins (UDTs), mirroring not only the physical environment but also intricate urban dynamics, may provide valuable insights for planners by predicting and analysing the impacts of urban scenarios. One of the main goals of planners is to develop scenarios that are pleasant and sustainable, and citizen's subjective visual perception and objective evaluation of the built environment play a pivotal role in this process. However, there is a lack of research on connecting with the public through UDTs for environmental perceptions, and no existing UDT framework is suitable for analysing visual features of urbanscapes and automatically predicting perceptions associated with photo-realistic rendering scenarios. To fill the gap, our study developed and implemented a novel UDT framework that is suitable for objective feature evaluation, subjective visual perception, and perception prediction of simulated scenarios. Objective feature analysis incorporates algorithms, such as computer vision, into the framework, to quantify a series of visual features in the built environment. Subjective visual perceptions (e.g.\ safety and lively) are captured using immersive virtual reality to gather public perceptions of different scenarios and learn patterns. Further, utilizing a photo-realistic rendering engine, high-quality renderings of textures and materials for UDT were achieved, and we proved their veracity based on a perception experiment. Afterwards, we employ the random forest algorithm for automated perception predictions of rendering scenarios. The implementation was demonstrated with a case study on an urban greenway in the central area of Singapore. We compared both the objective evaluation and subjective perception results, followed by a demonstration of automated visual perception prediction through photo-realistic scenario simulations, such as modifying vegetation density or introducing new architectural elements to the skyline, to predict the perception of scenarios before they are built, leading to more efficient and automated urban planning.

Keywords: Urban Digital Twin, Computer Vision, Virtual Reality

P13

Investigation of the impact of urban planning regulations on distributed energy system performance

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The performance of a Distributed Energy System (DES) in urban areas, exemplified by metrics such as Levelized Cost of Energy (LCOE), annual and peak load from grid, heavily hinges on urban forms. Research indicates that specific urban forms, such as a diverse land-use mix and low density, can enhance DES performance. However, practical urban form planning is often constrained by various urban planning regulations (UPRs), e.g. Street Block Plans, Urban Design Guidelines, Height Control Plans and Landed Housing Areas. Those planning regulations define the restrictions for urban form development, including plot boundaries, allowable land uses, maximum building heights and site coverage, which may prevent the urban form design from adopting the most energy-efficient forms. While the general correlation between urban forms and DES performance is evident, the precise impact of UPRs on DER performance remains uncertain. To bridge this gap, this study introduces an innovative methodology to quantify the impact of UPRs on DES performance, encompassing LCOE, annual load, and peak load. This approach integrates an urban form design model, a distributed energy system optimization model, and a City Knowledge Graph (CKG) model within a unified framework. To

demonstrate the efficacy of our methodology, we apply it to the mixed-use neighbourhood of One North in Singapore. Our findings reveal that the primary UPR variable affecting DES performance is the restriction on allowable land use, resulting in a 25% increase in LCOE, a 82% increase in annual load, and a 65% increase in peak load compared to a scenario without regulations. Strategically adjusting these land-use restrictions can bolster the deployment of energy-efficient buildings, thereby increasing PV generation potential. Conversely, the impact of building setback regulations on DES performance is relatively minor, with only a 5% increase in LCOE, an 8% increase in annual load, and a 7% increase in peak load. Adjusting these setback constraints strategically can enhance energy sharing and utilization, thereby reducing LCOE.

Keywords: Distributed Energy System, Urban Planning Regulations, Optimization, Cities Knowledge Graph

P14

Examining Health Inequalities in a Mixed-Income Residential Neighborhood in Singapore

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Studies in low-income and high-income neighbourhoods worldwide have found that health behaviours and health outcomes vary by neighbourhood characteristics and socioeconomic status. However, little is known about the influence of individual socioeconomic position and neighbourhood environment on the health behaviours of people living in mixed-income, high density neighbourhoods in Southeast Asia.

In this study we examined perceptions of health behaviours and neighbourhood environment to understand the impact of individual/environmental factors on health behaviours among residents of different socioeconomic backgrounds in a Singapore housing neighbourhood. A mixed-methodology comprising participatory asset mapping, Q-methodology, statistical analysis, and qualitative analysis was employed to collect and analyse data.

The results revealed that despite living in the same neighbourhood, having equal access to high quality infrastructure and amenities, the person-environment interaction in terms of health behaviours and perceptions was the highest in the middle-income segment, lowest in the lower-income segment, and moderate in the higher-income segment.

The findings suggest that planners and policy makers should focus on ensuring targeted intervention for different socioeconomic groups within the same neighbourhood to efficiently address health inequalities.

Keywords: Health Inequalities, Health Behaviors, Mixed-Income Residential Neighborhood, Q-methodology, Socio-economic Status

P15

Singapore´s Digital Urban Climate Twin: Analysis of Measures from Island to Neighborhood Scale

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Cities are required to adapt to the changing climate to protect wellbeing and health of their population. This requires measures that guarantee a sustainable development, decrease in anthropogenic heat emissions and an improvement of outdoor thermal comfort. Measures to address these challenges are manifold and may include changes in vegetation, urban design, transport, energy, building construction and urban climatology. To identify the optimal set of measures an integrated modelling approach is needed that takes the cities infrastructure, its heat emissions, the vegetation and landuse, the behaviour of people and the prevailing climate into account. The Digital Urban Climate Twin (DUCT), developed by the Cooling Singapore 2.0 project, tries to tackle this challenge by coupling relevant models with multiple sets of input data. In this work, we demonstrate the capabilities of the DUCT by showcasing the analysis of a set of measures at island and neighbourhood scale in Singapore. Time-resolved heat emissions of buildings, traffic, industry and powerplants are modelled and further integrated as gridded anthropogenic heat emissions into a meso-scale climate model of Singapore. Vegetation and land use is represented in the form of local climate zones. The DUCT explorer, an easy-to-use interface to the DUCT, allows its user to evaluate measures in an efficient and simplified manner. With this tool-set strategic long-term development scenarios such as the Greenplan 2030 for Singapore can be analysed at island wide scale. In a next step these results can be further integrated as boundary conditions into a micro-scale climate model, to evaluate the effectiveness of measures at the local neighbourhood scale. We showcase for a set of selected measures their impact on Urban heat and Outdoor thermal comfort in Singapore.

Keywords: Digital Twin, Measures to Improve Outdoor Thermal Comfort, Urban Climate

P16

Cooling Capacity of Urban Vegetation with Diverse Densities and Spatial Patterns in Tropical Cities, an experience from Singapore

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This study investigates the cooling capabilities of urban vegetation, which emerges as a vital and more adaptable alternative to mitigate urban heat. This is particularly essential in well-established urbanized areas, where the modification of urban morphology is often costly and impractical. Given the inherent heterogeneity of cities, a context-specific approach is applied in this study. Indices of

greenery spatial patterns, along with the urban morphology index (Sky View Factor), are mapped at an urban scale to select representative sites. A comparative analysis of the cooling capacity of urban greenery was conducted across selected sites. The results indicate that the cooling capacity of urban vegetation is significantly influenced by its spatial pattern (i.e., green cover density and green aggregation index), as well as the interplay between urban contexts and the background climate conditions. A better understanding of how and where to integrate urban vegetation into cities to maximize the cooling capacity is gained. A case-by-case approach emphasizes the influence of the local climate conditions, particularly the wind environment. Key insights include increasing vegetation density and aggregation index when the wind environment permits, reserving wind corridors to facilitate vegetation cooling, and strategically locating the vegetation to make use of the directional cooling effects. These findings are essential to guide the urban design implementation to improve the cooling capacity of urban vegetation based on the local urban context.

Keywords: Urban Vegetation, Cooling Capacity, Greenery Spatial Pattern, Urban Greenery Design Guidance, Tropical Cities

P17

An Enhanced Transit Accessibility Evaluation Framework by Integrating Public Transport Accessibility Levels (PTAL) and Transit Gap

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Rapid urbanization has presented many challenges, notably spatial imbalances between the transit supply and demand within cities. The inequitable distribution of transit supply, which include the transit infrastructure and services, may lead to formation of areas where transit is under provisioned. This work aims to develop an enhanced framework for measuring spatial disparities in accessing transit systems by combining established concepts of Public Transport Accessibility Levels (PTAL) and transit gap. The proposed framework incorporates PTAL as a supply indicator and transit dependent population as the demand indicator while estimating the transit gap. PTAL takes into account the intricate relationship between transit infrastructure and transit services, an aspect that was overlooked by the previous studies on transit gap. Inclusion of PTAL enhances the transit gap evaluation method by offering a deeper understanding and a holistic perspective on the transit system. We demonstrate the proposed approach with an application in Singapore. Additionally, we propose a new classification system based on PTAL and transit gap to distinguish areas where high transit gap is a result of very high demand rather than poor supply. Results show that 44.82% of the transit dependent population in Singapore lives in high transit gap area out of which 4.69% population stays in transit desert zones, where supply is poor, and 40.13% lives in transit over utilised zone, where demand is very high. The study also developed a simple decision framework based on PTAL and transit gap scores to suggest effective policy measures for reducing the spatial disparity in transit system accessibility. The findings from the work can aid policymakers and transport planners in land-use and transport planning of cities.

Keywords: Equivalent Doorstep Frequency, Transit Demand, Transit Supply, Transit Desert

P18

The Effects of Activity Centre Design, Ownership, and Governance on Neighbourhood Complexity in Singapore

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My research looks at the physical subsystems of the city, its neighbourhoods, and their activity centres, in the light of the theory of complex adaptive systems. Complexity theory argues systems that function as complex adaptive systems will have greater mass than those that function as mechanical ordered systems.

The Singapore government has used state planning and land ownership to develop and expand the city via 23 self-contained new towns since 1965. Prior to 1993, neighbourhoods within these new towns were planned and developed with three levels of old generation activity centres. These activity centres contained diverse uses connected by outdoor plazas, malls, and sidewalks. Post 1995, activity centres have been developed as new generation internally focused multi-level shopping malls. Our research uses qualitative statistical data and observational analysis to compare mass as numbers of premises, businesses, and jobs between neighbourhoods from both eras.

The research shows the design and governance of old generation activity centres enabled them to develop and evolve complexity. In comparison, the new generation centres have a dynamic of top-down mechanical order. As complexity theory predicts, the research shows pre-1993 new-town neighbourhoods with complex old generation activity centres have greater mass in the form of premises, businesses, and employment than post 1993 neighbourhoods with ordered new generation activity centres.

Keywords: Activity Centres, Singapore New-towns, Neighborhoods

P19

The Prospect of Collective Climate Action: Knowledge, Perceptions, and Expectations of Net Zero Amongst Singapore's Citizenry

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The 2015 Paris Agreement limits temperature increase to 1.5°C – a challenging goal whose success hinges upon achieving Net Zero greenhouse gas (GHG) emissions globally by mid-century. To this end, many countries and cities have set ambitious climate targets that, to date, have disparate outcomes. While a complex set of interlinked factors explains such dissimilar progress, it is strikingly clear that the current approach of leveraging technological innovation to achieve Net Zero needs to be complemented with community support. We need communities and individuals to be active

contributors through their collective day-to-day actions and support for Net Zero initiatives and policies.

We use the case of Singapore (which aims to achieve Net Zero by 2050) to establish a critical understanding of how citizens understand and perceive Net Zero targets and policies in order to develop more effective public communication and campaign strategies. Engaging a representative sample of 2,304 respondents, we also explored their motivation for climate-friendly actions. Our analysis revealed that: (1) In general, the public had a good understanding about the concept of "Net Zero", which could be further strengthened with purposeful visualisation and infographics. (2) There was limited knowledge of how different pro-environmental actions taken by individuals contributed towards climate action. (3) Different demography of respondents had different preferences for climate-friendly actions and older respondents appeared more likely to engage with low-cost, high-effort pro-environmental actions. (4) The support for Government actions toward Net Zero was generally strong and responses to a contingent valuation question revealed that individuals were willing to contribute a monthly average of $50 towards implementation of Net Zero measures. (5) The combination of people's desire for more information about Net Zero and the high level of trust in Government communication presents opportunities for the Government to promote higher impact climate actions. Our findings suggest a maturity of the citizenry with potential for social mobilisation towards collective climate action.

Keywords: Net-zero, Climate Action, Public Communication, Climate Knowledge, Public Perception, Singapore

P20

Developing Private Car Trip Generation Models for Public Housing in Singapore Using Secondary Data

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Trip generation modelling is an important aspect of transportation planning, finding applications in traffic impact assessments of individual developments to travel demand modelling of larger metropolitan areas. The new and emerging secondary data sources on transport provide an opportunity of using them in the development of trip generation models without heavy cost incurred on data collection. This study uses car park lot availability data from public housing estates in Singapore along with other secondary data sources to estimate private car trip generation models for pre-pandemic, pandemic and post-pandemic stages of the COVID-19 pandemic. Our results show that the use of average trip rate, an industry standard, results in poor prediction of trip generation for public housing blocks in Singapore. At the same time, a regression model developed using land use, built environment and transit accessibility variables provides much better trip generation estimates. To evaluate the impact of the COVID-19 pandemic on the trip generation, we separately estimated the model for three stages of the COVID-19 pandemic and found that the performance of the trip generation model has improved during the pandemic stage, only to come back to its original pre-pandemic level after the pandemic. The results also show that the influence of transit accessibility on private car trip generation become insignificant during the pandemic stage but is significant during pre-pandemic and pandemic stages. Similarly, we also found that the significance of hawker centres

on private car trip generation has increased during the pandemic stage. Our study demonstrates the potential use of secondary data in land-use and transport planning applications by showing that trip generation models with a better performance than that of the trip rates can be derived using readily available secondary data sources and thereby the costly travel surveys can be replaced for some applications.

Keywords: COVID-19 Impact, Residential, Trip Attraction, Trip Production

P21

Enhancing Social Well-being and Public Health in Urban Environments: Insights from Singapore Neighbourhoods

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Addressing social well-being and public health concerns stands as a paramount challenge in designing liveable urban spaces, particularly within the distinctive urban landscape of densely populated Singapore, requiring meticulous and effective urban planning strategies. Central to this endeavour is grasping the intricate relationship between the built environment and the social dynamics of local communities. Our study posits that the design of the built environment plays a pivotal role in shaping social activities, thereby influencing community engagement and social outcomes. Key among these outcomes are social capital and physical activity levels, both integral to fostering community cohesion and enhancing residents' health, consequently mitigating long-term healthcare costs. Employing a mixed-methods approach, we utilised both quantitative and qualitative methodologies to explore residents' perceptions of various physical elements within the built environment, encompassing amenities, public spaces, and transportation options. Data were collected from official sources, questionnaire surveys, and in-depth interviews of participants across three selected neighbourhoods in Singapore. In quantitative analysis, we developed structural equation models to examine the interplay between different aspects of the built environment and social outcomes, revealing that perceived inclusivity and quality significantly influence social capital, while indirectly impacting physical activity through social capital as a mediator. In qualitative analysis, we performed content analysis of interview data to unveil multifaceted barriers to social interaction, ranging from physical layout and personal lifestyles to privacy concerns, cultural disparities and communication challenges. While residents appreciate existing amenities, there's a collective aspiration for more diverse options, calling for inclusive, healthy, and vibrant urban environments, which should recognise the pivotal role of social capital and healthy living in nurturing thriving communities. We believe our study offers valuable insights for urban planners, delineating how built environment factors can positively impact social dynamics and physical activity levels, facilitating the realisation of desired social outcomes in urban settings.

Keywords: Qualitative and Quantitative Methods, Social Outcomes, Spatial Planning, Urban Space

P22

What Kind of Nature Fosters Social Ties in Cities? Learning from Singapore and Tokyo

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An important contribution of nature to health promotion is linked to social well-being, of which social tie is a key measure. Cities continuously underline the importance of nature provision, particularly at the everyday-life level, in stimulating social interactions that can foster social ties. However, what kind of nature and how we plan and design nature that fosters social ties remains fuzzy. Increasingly, studies have observed that people's perceptions of nature matter more in fostering social ties than spatial or physical attributes of nature. Nevertheless, the relationship mechanisms between various attributes of nature, perceived and spatial/ physical, and social ties remain inadequately discussed. Echoes other similar studies, our study of several neighbourhood green spaces in Singapore and Tokyo shows positive associations between multiple perceptions of nature and social ties. The associations, nevertheless, are not necessarily direct. Perceptions of nature shape spatial experiences, which we define as Sense of Vitality, Sense of Delight, and Sense of Engagement, distinctively. These spatial experiences are linked to motivations to use nature (e.g. health-oriented, family-oriented, socializing-oriented, relaxation-oriented) which can allow either incidental or deliberate social interactions to occur and social ties to grow. There are several differences when comparing Singapore and Tokyo, especially concerning which perception and spatial experience matter most in fostering social ties. For instance, the Sense of Engagement is more important in fostering social ties in Singapore while the Sense of Vitality is more important in Tokyo. Contexts such as cultural cognizance towards nature and planning interventions may also contribute to the differences. The findings from this study suggest the critical role of citizen science in synthesizing recommendations that inform the planning and design of nature in cities and planning policies.

Keywords: Urban, Nature, Social Ties/ Social Capital, Perceptions

P23

Geo AI Unravels the Effects of Urban Thermal Environment on Utility-scale Floating Photovoltaic Electricity Generation

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Utility-scale photovoltaic farming has been increasingly being integrated into national grids for renewable energy transition and climate change mitigation. However, the dynamic urban thermal environment has an immediate impact on photovoltaic conversion efficiency (PVCE) while unstable weather significantly determines horizontal land surface solar irradiation. This results in an unpredictable uncertainty in electricity generation, posing great challenges to the planning of PV

installed capacity and the operation of grid load balancing. To tackle this problem, we have developed a GeoAI-facilitated geospatial model aimed at accurately estimating monthly electricity generation considering the influence of both thermal environments and weather variability. The model consists of four modules. First, we retrieved photovoltaic surface temperatures (PVSTs) from thermal satellite imagery and collected meteorological data to quantify the varying thermal conditions. Second, the significance of each influential factor in PVST estimation was assessed using metrics of MDI, PI, and SHAP. Third, three comparative machine learning models (i.e., SVM, RF, and eXtreme Gradient Boosting) were developed to build regressions between the identified influential factors (i.e., air temperature, humidity, air pressure, and wind speed) and PVSTs. This allowed for precise estimations of heterogeneous PVSTs over both time and space. Fourth, the spatiotemporally corresponding PVCEs were calculated, leading to a more accurate estimation of monthly electricity generation compared to the conventional method. We conducted an empirical investigation in four utility-scale floating PV farms in Singapore, it was found that their PVCEs exhibited small variations and monthly electricity generation ranged between 10,000 to 14,000 MWh, benefiting from relatively consistent climate and the water's cooling effect throughout the year in Singapore. The simplicity and effectiveness of the proposed model explicitly demonstrate its impact on estimating utility-scale PV electricity generation, particularly when urban thermal effects are significant.

Keywords: Floating Photovoltaic Electricity Generation, GeoAI, GIScience, Remote Sensing, Urban Thermal Environment

P24

Towards High Resolution Urban Weather and Climate Modelling for Singapore: Overview of Effort at CCRS

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Singapore, as a coastal city-sate located within the deep tropics, experiences unique tropical weather and climate that are further complicated by its rapid urbanization. The extensive urban development, characterized by buildings and pavements, significantly modifies the surface energy balance and local atmospheric conditions. Given its high population and property density, cities like Singapore are particularly vulnerable to meteorological hazards, such as the urban heat island, flash flooding, air pollution, and sea-level rise. Understanding the dynamics between urban developments and associated weather and climate in Singapore is crucial for sustainable planning and policy formulation. Since 2016, the Centre for Climate Research Singapore (CCRS) under Meteorological Service Singapore (MSS) has started to develop an urban modelling system known as uSINGV. This system, which is adapted from the Unified Model from the UK Met Office, is designed to investigate the impacts of urban developments on local weather and climate. This presentation will provide a comprehensive overview of research effort at CCRS, emphasizing the development of the high-resolution 100m uSINGV system. It will focus on the model development, validations with observations, key research findings, and on-going projects and collaborations. With the completion of Singapore's Third National Climate Change Study V3, this talk will also share plans to leverage the latest V3 data to further downscale the future local climate to the sub-km scale through uSINGV. This talk is deigned to inform and enhance the understanding of policymakers, urban planners, and scientists on CCRS' effort, with

the aim to facilitate the evidence-based strategies for climate change mitigation and contribute to a more resilient and sustainable Singapore.

Keywords: uSINGV, Urban Meteorology, Weather and Climate Modeling, High Resolution

P25

Elevating Urban Ecology: Assessing the Connectivity of Skyrise Greenery in Singapore

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In its ambition to evolve into a "City in Nature", Singapore is committed to adding 200 hectares of skyrise greenery into its urban landscape by 2030. Beyond their recreational functions, these elevated green spaces emerge as potential ecological hubs, enriching urban ecosystems through habitat provision and biodiversity enhancement. This study presents a systematic methodology for assessing the ecological connectivity of vertically integrated urban green spaces at a neighbourhood scale, using the Wilmar building and its adjacent park within the city's one-north district as a prime example. We use network analysis based on graph theory to study ecological network connectivity. The method represents ecological systems as networks of interconnected nodes (representing species, habitats, or ecological processes) and edges (representing interactions, such as movements or competition). By establishing each urban green space as a node and considering physical and visual accessibility as links, we employ multi-ecosystem services network analysis to evaluate connectivity measures for each node. Additionally, we utilise the Singapore Index on Cities' Biodiversity (SI) toolkit to establish quantitative metrics for assessing biodiversity scores across the study area. The results underscore the significance of vertically integrated green spaces as critical habitats for birds and pollinators, thus serving as vital components of urban ecological networks. The effectiveness of these spaces as ecological connectors is influenced by various design elements, including structured landscapes, multi-tiered planting schemes, plant diversity, the incorporation of native species, and maintaining continuity in the plant palette from ground to elevated levels. This research contributes to understanding vertical ecological connectivity within urban built environments by explaining the ecological functionality of skyrise green spaces. It offers critical insights into the current discussion about urban sustainability and biodiversity conservation, underpinning the development of cities that are both adaptive to climate change and resilient.

Keywords: Skyrise Greenery, Ecological Connectivity, Network Analysis, Biodiversity Conservation, Urban Ecosystems, Sustainable Urban Development

P26

The Impact of Natural Urban Terrain on Urban Wind Environment in High-Density Neighborhoods using LES Turbulence Model

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Microclimatic interactions are complex, and due to limitations of computational resources, it is often neither feasible nor efficient to model and replicate the real-world built environment down to the last detail. As a result, substantial simplifications, pertinent to the model geometry, are adopted like the assumption of a flat topography. The impact of topography on wind flow has been studied at different spatial and temporal scales, yet the influence of natural urban terrain on the local wind conditions is not well understood. In this study, we investigate the impact of natural urban terrain on mean wind speed and air temperature at the pedestrian level. We conduct a numerical study using Large Eddy Simulation (LES) turbulence model for a high-density residential neighborhood in Singapore modeled with realistic irregular terrain. We focus on two wind variations (1) low wind speed and high temperature conditions for which the atmospheric boundary layer exhibits unstable thermal stratification that is important for resilience studies and (2) annually averaged wind conditions with neutral thermal stratification that are conventionally used for urban wind studies. A statistically significant difference in mean wind speed was observed between the model with natural topography and that with homogenous flat terrain for the first scenario. More importantly, we observe a localized effect based on building density and proximity to high terrain with spatial averages as high as approximately 0.8 m/s for both the cases. This result may provide a new basis in considering urban terrain for high-fidelity simulations in climate sensitive city planning and design.

Keywords: Urban Wind Environment, Urban Terrain, LES Model, Non-isothermal Simulation, High Density Neighborhood

P27

100-m Resolution Urban-Scale Modelling of Extreme Rainfall in Singapore

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Singapore, being a tropical island city-state located near the equator, maintains a consistently warm and humid climate throughout the year. The city faces increased vulnerability to extreme weather events, such as heavy rainfall and flash floods, owing to its unique climate and rapid urbanization. The weather systems affecting Singapore that can lead to heavy rainfall include localized thunderstorms, Sumatra squalls, and monsoon surges. Modelling studies have suggested that urbanization can impact the weather in coastal cities like Singapore through complex land-air interactions. Urbanization is favorable for generating localized wind convergence zones, fostering enhanced convection and heavy

rainfall. Furthermore, circulations resulting from differential surface heating of the boundary layer between different land covers create an environment conducive to localized convergence and thunderstorms. This study presents a set of case studies involving afternoon localized wind convergence, Sumatra squalls, and monsoon surges leading to heavy rainfall events over Singapore. The analysis utilizes the uSINGV model with a 100-meter grid spacing, which is a sub-kilometer model developed by CCRS/MSS. This study is focused on assessing the performance of the high-resolution uSINGV model in capturing the underlying processes governing the initiation, organization, and development of deep convections leading to extreme rainfall in Singapore and nearby regions. Results from this study will be used to further develop advanced urban-scale numerical modelling, which allows us to provide more detailed weather and climate information to support various user sectors.

Keywords: Weather and Climate, Urban Modelling, Extreme Rainfall, uSINGV Model

P28

Singapore's Collaborative Modelling Approach to Support Land Use-Transport Integrated Planning

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For decades, Singapore's planning agencies have fostered a collaborative approach to integrated planning, and actively leveraged data and modelling tools. The Traffic Quantification & Transport Model (TQTM) process implemented by the Urban Redevelopment Authority (URA) and Land Transport Authority (LTA) exemplifies this synergy, supporting national strategic planning exercises like the Long-Term Plan Review and Master Plan Review; Downstream, localised transport simulations support decision-making on site-specific planning and development control parameters. To support more multi-objective, multi-scalar, and multi-team assessment, URA and LTA have embarked on a joint initiative named "SimSG". This initiative is aimed at bolstering not only technical data and modelling capabilities, but also practitioners' access to a wide suite of tools. It encompasses: 1) automation of back-end data processing to enhance efficiency and reduce potential errors; 2) cloud-based integration of land use and transport models to speed up model iterations; and 3) transformation of existing models and development of new tools to create novel capabilities for agile scenario testing. The SimSG initiative transcends the immediate benefits for URA, LTA and other government agencies, envisioning future accessibility for academic and industry professionals. This seeks to foster a robust urban planning ecosystem, reinforced by regular knowledge exchange and collaborative innovation. This presentation delves into the data-driven and people-oriented approaches underpinning this endeavour, unpacking the multifaceted SimSG vision and initiative.

Keywords: Data-Driven Decision Making, Land Use-Transport Interactions, Planning Iterations, Transport Model

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100 m uSINGV Modelling of the Record-Breaking Extreme Heat in Singapore on May 2023

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The last IPCC report emphasizes the critical need for specific attention to the exacerbation of heat waves in future years. A record-breaking extreme high temperature event was observed, with the maximum air temperature over 37 degree Celsius on May 13th 2023 at Ang Mo Kio station Singapore. This study aims to conduct the numerical simulations of this extreme heat event and comprehensively investigate its main contributing physical factors. The study employs 100m uSINGV, a high-resolution coupled urban-atmosphere research model developed by the Center for Climate Research Singapore (CCRS) based on the Unified Model from UK Met Office. uSINGV has used the updated local land use land cover and urban morphology datasets and finely tuned model physics tailored for tropical urban weather and climate. We analyze the model results and compare with meteorological observations (e.g. weather stations and radio sounding) and to lower resolution models from several state-of-art weather forecasting systems to better understand the intricate interactions of natural and urban environments in shaping extreme events. Furthermore, we will focus on the urban heat island effects and explore the impacts of land-use changes to identify the key drivers for urban extreme heat events. The findings from this research will contribute to a deeper understanding of the complex dynamics driving extreme hear events in this specific urban context in Singapore and provide guidelines for climate resilience strategies in tropical urban environments.

Keywords: Climate Resilience, Extreme Heat Events, High-resolution Model, Urban Climate

P30

Urban Densification and Microclimate Optimization for Liveable Cities: A Case Study in Altstetten-Albisrieden, Zurich

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The increasing urban population has driven densification to the forefront of urban development. It is essential to have an urban planning strategy that comprehensively understands the impacts of densification on the environmental, social, and economic dimensions at the district and the city scales. In Switzerland, densification is a legally binding policy objective to develop housing and job positions within existing urban boundaries. However, the challenge is to accommodate the population growth without compromising the high quality of living. Zurich is a prime example, where the urban area needs to house around 23% of the increase in the resident population and workplaces accordingly. This study, in collaboration with the City of Zurich, aims to find strategies for urban densification and transformation in the context of Zurich by investigating the Altstetten-Albisrieden district. This district

is a suitable real case as it represents the city's social and geographic situation and has excellent potential for hosting population growth. The study generates eight densification scenarios and investigates their impacts on the microclimate of urban areas at the city scale. The scenarios explore urban development measures, such as completely redeveloping the district, partially rebuilding projects older than fifty years, building retrofits and preserving green spaces. Two online tools, ArcGIS Urban and Microclimate Digital Platform (MDP), are hired to visualize, simulate, and evaluate each densification scenario, as well as identify possible challenges and strategies. The analysis of different scenarios and evaluation of the microclimate suggest that appropriate measures for densification can lead to the development of liveable cities. In this regard, the design of building typologies should be considered thoughtfully, along with the provision of green spaces in the built environment, as they play a crucial role. These measures can improve the microclimate at the city scale by mitigating urban heat islands, generating cooling-air corridors, and enhancing outdoor thermal comfort. Moreover, the study has identified specific strategies for densification that can be implemented in areas with critical microclimate situations for future development.

Keywords: Densification, Scenario Analysis, Microclimate, Zurich

P31

Global Streetscapes – Benchmarking Computer Vision Models for Urban Science and Analytics

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Street view imagery (SVI) became a key data source for sensing urban environments, benefitting numerous urban research topics such as urban morphology, health, greenery, and accessibility. Billions of images around the world have been made available by commercial services such as Google Street View, and crowdsourced platforms such as Mapillary and KartaView where anyone from anywhere can upload imagery while moving. However, while the data tends to be plentiful and have high coverage and quality, and is used to derive rich insights, it remains simple and limited in metadata as characteristics such as weather, quality, and lighting condition remain unknown. This completeness challenge makes it difficult to identify images with suitable characteristics for a particular use case, potentially affecting usability and reliability. Within the Global Streetscapes dataset, a worldwide dataset of 7 million crowdsourced and free-to-use SVIs sampled from 677 cities, we manually tag 10,000 images for eight visual-contextual attributes such as panoramic status, lighting condition, view direction, weather, platform, quality, presence of glare and windshield reflections. We trained state-of-the-art deep learning models on these features and obtained accuracies of 99.9%, 96.2%, 87.4%, 75.5%, 68.3%, 79.9%, 94.1%, and 78.6%, respectively. The models and training settings are also included in the dataset with a reproducible framework to 1) sample and synthesise crowdsourced SVIs from two different platforms, 2) enrich them with rich auxiliary information to facilitate their usage

and integration with external datasets, and 3) enable future updates by fetching the latest available data from the aforementioned platforms. This labelled dataset and its trained models offer, for the first time, a benchmarking dataset and baseline computer vision models for different visual-context attributes in urban science and analytics.

Keywords: Data Fusion, GeoAI, Machine Learning, Street View Imagery, Urban Analytics

P32

Mapping Spatial Analysis Methods to User Cognition and Behaviour

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Architectural and urban design aim to create spaces accommodate human needs, public well-being, and safety. Traditionally reliant on subjective intuitions by designers, the field is undergoing a transformative shift towards more objective and data-driven decision-making. Emerging evaluation methods like space syntax, isovist analysis, and agent-based modelling bring diverse tools and software platforms with varied theoretical foundations. However, they are more commonly employed by researchers retrospectively (e.g. in post-occupancy evaluation studies), with limited utilization by practitioners due to multiple practical reasons.

This research seeks to develop a comprehensive taxonomy and guide for researchers and architects alike, highlighting widely used tools and methods available for integrating user cognition and behavioural knowledge into architectural design practice. The objective is to empower both communities with a nuanced understanding for effective tool selection and utilization, including their strengths, limitations, and suitable use cases. By mapping existing tools, this study also aims to identify gaps and opportunities for further research.

Methodologically, the research first employs a systematic review to identify widely used computational tools. It then performs a comparative analysis of selected tools, including conceptual analysis, practical evaluation, testing them in common scenarios and complemented by surveys and interviews within the industry to gauge current utilization and usability. This multifaceted approach positions the research to provide insights into cognitive aspects, their respective key metrics, varying theoretical bases, and practical use cases for each tool, underlining their effectiveness against architectural design workflow criteria.

Findings from this comprehensive exploration contribute to the development of a complete taxonomy which aims to enable design practices to adopt human-centric and evidence-based design workflows. The significance lies in empowering designers with the knowledge to make better data informed decisions, ensuring the integration of tools that align with their specific needs and design focus regarding cognitive considerations inherent in architectural and urban design.

Keywords: Architectural Design, Evidence-Based Design, Spatial Analysis, Spatial Cognition

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