Dense and Green Cities for a Nature-Positive Future

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URBAN SOLUTIONS AND SUSTAINABILITY
R&D CONGRESS 2023
BUILDING SUSTAINABLE, RESILIENT, AND LIVEABLE CITIES OF TOMORROW
4TH - 5TH OCTOBER 2023

CREATE ETH zürich NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE NUS National University of Singapore SUTD SINGAPORE UNIVERSITY OF TECHNOLOGY AND DESIGN

(FCL) FUTURE CITIES LABORATORY GLOBAL

Singapore Green Plan 2030

City in Nature Vision

- one of the 6 critical pillars for achieving net zero targets by 2050
- intensify nature in gardens and parks
- restore nature into the urban landscape
- strengthen connectivity between Singapore's green spaces and urban systems
- shared ecosystem for all – shift from 'people-centric' to 'life-centric'

2023

SG GREEN PLAN

The Singapore Green Plan 2030 is a national sustainability movement, positioning us to achieve our target of net zero emissions by 2050. It is a living plan which continues to evolve. Here are the key updates and initiatives announced by Green Plan Ministries in Committee of Supply 2023.

GreenPlan.gov.sg

Jointly led by: Ministry of Education Singapore; MND Singapore; Ministry of Sustainability and the Environment Singapore; MTI Ministry of Trade and Industry Singapore; Ministry of Transport Singapore

SG GREEN PLAN

The Singapore Green Plan 2030 is a national sustainability movement which seeks to rally bold and collective action to tackle climate change.

It is a living plan which will evolve as we work with Singaporeans and partners from all sectors to co-create solutions for sustainability. Let's work together to make Singapore a green and liveable home.

City in Nature

Green, Liveable and Sustainable Home for Singaporeans

- Plant 1 million more trees, and have every household within a 10-minute walk from a park by 2030
- Develop over 130 ha of new parks, and enhance around 170 ha of existing parks with more lush vegetation and natural landscapes by end-2026
- Add 1000ha of green spaces by 2035

Green Government

Public sector will lead on sustainability

- Be exemplary in taking sustainability action, including to peak public sector carbon emissions around 2025, ahead of national target
- Encourage and enable citizens and businesses to adopt sustainability practices, such as through green procurement

Sustainable Living

Strengthen Green Efforts in Schools

- Introduce an Eco Stewardship Programme to enhance environmental education in all schools
- Work towards two-thirds reduction of net carbon emissions from schools sector by 2030
- At least 20% of schools to be carbon neutral by 2030

Green Commutes

- 75% of trips during peak periods to be on mass public transport by 2030
- Triple cycling path network to 1,320km by 2030, from 460km in 2020
- Expand rail network to 360km by early 2030s, from around 230km today

Green Citizenry: Reduce waste and consumption

- Reduce amount of waste to landfill per capita per day by 20% by 2026, and 30% by 2030
- Reduce household water consumption to 130 litres per capita per day

Energy Reset

Cleaner-energy Vehicles

- New diesel car and taxi registrations to cease from 2025, with all new car and taxi registrations to be of cleaner-energy models from 2030
- Further revise road tax structure to bring down road tax for mass-market electric cars
- Target 60,000 electric vehicle (EV) charging points by 2030, with 8 EV-Ready Towns by 2025

Greener Infrastructure & Buildings

- Green 80% of Singapore's buildings (by Gross Floor Area) by 2030
- 80% of new buildings (by Gross Floor Area) to be Super Low Energy buildings from 2030
- Best-in-class green buildings to see 80% improvement in energy efficiency (over 2005 levels) by 2030

Sustainable Towns & Districts

- Reduce energy consumption in HDB towns by 15% by 2030

Green Energy

- Quadruple solar energy deployment to 1.5 gigawatt-peak by 2025
- Tap on cleaner electricity imports, and increase R&D on renewable energy and emerging low-carbon technologies

Green Economy

Sustainability as New Engine of Jobs and Growth

- New Enterprise Sustainability Programme to help local enterprises adopt sustainability practices
- Develop Singapore to be a carbon services hub, and a leading centre for green finance in Asia and globally
- Develop Jurong Island to be a sustainable energy and chemicals park
- Leverage opportunities in sustainable industries to create good jobs for Singaporeans

New Investments to be Carbon and Energy Efficient

- Seek new investments to be among the best-in-class in energy/carbon efficiency

Resilient Future

Safeguarding our Coastlines against Rising Sea Levels

- S$5b dedicated to coastal and drainage flood protection measures
- Formulation of coastal protection plans for City-East Coast, North-West Coast (Lim Chu Kang and Sungei Kadut) and Jurong Island by 2030

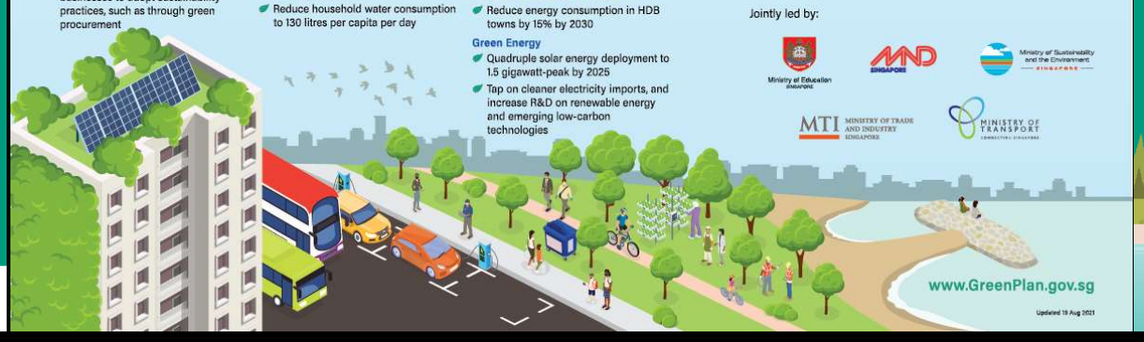
Safeguarding Food Security

- Develop the capability and capacity of our local agri-food industry to produce 30% of our nutritional needs locally and sustainably by 2030

Keeping Singapore Cool

- Moderate the rise in urban heat, such as with cool paint and by increasing greenery

Jointly led by: Ministry of Education Singapore; MND Singapore; Ministry of Sustainability and the Environment Singapore; MTI Ministry of Trade and Industry Singapore; Ministry of Transport Singapore



www.GreenPlan.gov.sg

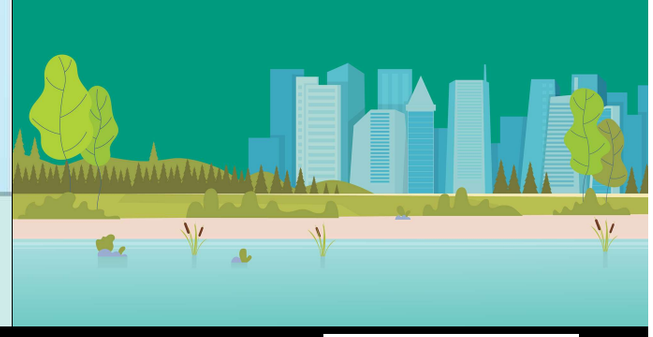
Updated 19 Aug 2023

2023

CITY IN NATURE

CONSERVING OUR BIODIVERSITY

- *Increase the target for restoration and enhancement of forest, coastal and marine habitats from 30 hectares to 80 hectares by 2030, to help our native biodiversity thrive in our ecosystem*



Dense and Green Cities for a Nature – Positive Future

Dense and Green Paradigm

Singapore – Capital City for Vertical Greenery*

Greenery becoming a key component to making high-density urban environments liveable
Density and **Sustainability** become mutually beneficial and interdependent

VERTICAL CITIES

Vertical Living as Sustainable Urban Solution

emergence of a three-dimensional urban space, where “the horizontal ground plane of a city begins to ‘thicken’, and growth is through vertical densification in addition to lateral spread” (Cairns, 2016).

Density Complexity Verticality

DENSE + VERTICAL + GREEN

Liveability: Key Measure for Sustainable Dense and Green Cities

“the need to see cities as dense and green spaces where integrating ecological principles within high-density urban planning has proven that in most liveable cities, density and quality of life were not mutually exclusive, but rather mutually beneficial” (Schroepfer, 2016, 2

Vertical extensions of urban greenery

Elevated urban green networks adding new dimensions of public space for high-density cities

Urban intensifications in the form of vertical urban planning and design have taken on a more **ecological discourse** in the context of global climate change, with integrated vertical urban greenery gaining significance as a critical planning and development tool for ‘vertical cities’ to achieve a high-quality living environment that balances ecology, sustainability and liveability.

Cairns, S. (2016). 3D City, 2D Urbanity? The Singapore Architect, 04, 91–94.
Schröpfer, T. (2020). Dense + Green Cities: Architecture As Urban Ecosystem (1st edition). Birkhäuser.

** See a+u 2012,*

Sustainable to Regenerative

Urban Ecosystems Approach

- Urban developments are driven by solutions that are environmentally enhancing and establish restorative relationships with the natural systems
- Creating cities functioning as living systems, where human activities align with natural processes and cycles.

Systems and process connect

Dynamic interactions between human and nature
Urban nature, where humans become an integral part of the natural processes and contribute positively to ecological balance

Net-positive design

Designs that are driven towards contributing positively to the natural environment, going beyond doing less damage or a net-zero approach

Changing the transformational scales

Shifting deeper into the realms of sustainability and taking a holistic view of a thriving living process (natural + human)
Social, ecological, environmental systems work together instead of against or at the cost of each other

Performance-based Design

Research driven scientific approach to informed design practice
Integrate new tools and methods for predictive planning and design

Placemaking to Placekeeping

Building social resilience through biophilic communities
Adding a layer of responsibility to the sense of belonging
Engaging long-term as an integral part of the life cycle

- self-regulating
- biological processes
- outside the manufactured realm
- self-sustaining
- adaptable and resilient

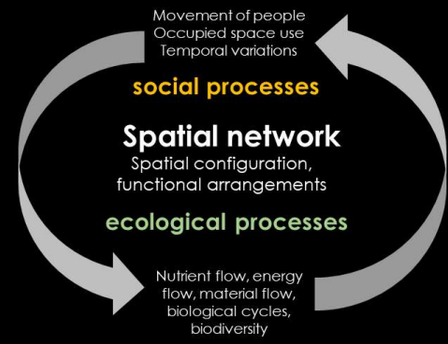
natural systems

urban ecosystems

ecological and anthropogenic systems are mutually dependent and beneficial

- built for performing specific function
- mechanical processes
- manufactured realm
- not self-sustaining by itself
- not adaptable and resilient by itself

built systems



user-centric

Performative Buildings

Dense and Green Building Typologies (2019)

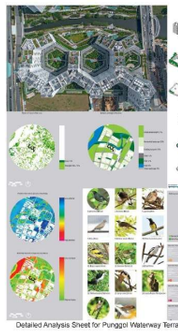
- Key collaborators were SUTD, ETH Zurich, NParks, CLC, BCA, URA, HDB
- The study systematically analysed the dense and green building typologies' environmental, social, architectural, economic, and aesthetic benefits and their potential to function as part of a larger urban landscape ecosystem.

DENSE AND GREEN CITIES
Architecture as Urban Ecosystem

The presented research explored the interaction between buildings and the city as ecological systems through the questions of concept, planning, design, technology and not least experience. The study evaluated the desne and green building typologies for their urban, architectural, social, envicronmental, ecological and economic benefits. The insights gained were consolidated as design strategies in that the integration of green and public spaces becomes integral to the design and form of buildings and not merely functional additions. This included structural considerations as well as considerations regarding the integration with other building systems. The initial explorations involved multi-dimensional analysis of 600 national and international dense and green projects. Six in-depth case studies were identified for detailed research. The project was multidisciplinary, requiring expertise in urban planning, urban design, architecture, landscape architecture, building technology, social sciences and plant ecology. The study concluded that dense and green buildings are effective in the provisioning, regulating, socio-cultural, supporting and economic services in dense urban environments. In addition, when connected and becoming part of larger urban ecological systems, these integrated developments can potentially produce additional benefits at a larger scale.

Exhibitions - FCL Dense and Green Building Typologies: Architecture as Urban Ecosystem at Venice Architecture Biennale 2018

Exhibitions - Dense and Green Cities: Architecture as Urban Ecosystem at National Design Centre Singapore, 2020



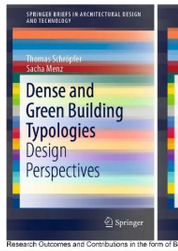
Detailed Analysis Sheet for Punggol Waterway Terraces 1 Singapore

Detailed Analysis Sheet for Skyville@Dawson Singapore

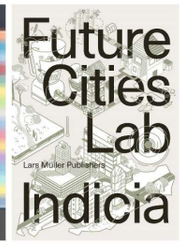
Urban Scale

- Preserve and extend large-scale urban green and blue systems such as forests, river networks and green corridors to create ecological connectivity and natural recreational spaces
- Consider total quantum of landscape areas provided by all developments in walkable radius or total quantum added to an urban green corridor or a park to establish continuous landscape areas
- Maximize total landscape area coverage, permeable surface coverage, vegetated area coverage, and density of vegetation
- Consider appropriate height and distance between landscape areas to provide spatial and visual continuity as well as people's movement and ecological connectivity across adjacent developments

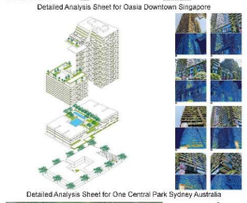
Research Outcomes as Urban Scale Integrated Greenery Design Strategies for Dense and Green Buildings



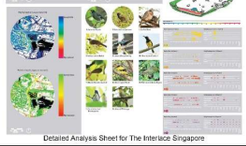
Research Outcomes and Contributions in the form of Book Publications



Detailed Analysis Sheet for Oasia Downtown Singapore



Detailed Analysis Sheet for One Central Park Sydney Australia



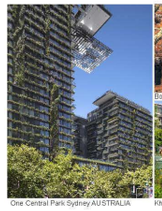
Detailed Analysis Sheet for The Interlace Singapore

The Interlace SINGAPORE

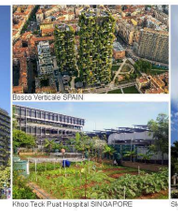
Punggol Waterway Terraces 1 SINGAPORE

Solaris SINGAPORE

Eight Identified In-depth Case Studies of Dense and Green Buildings



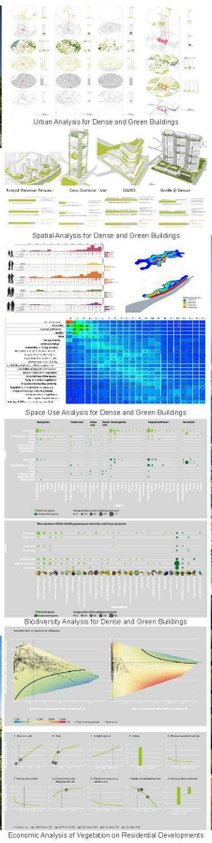
One Central Park Sydney AUSTRALIA



Khoo Teck Puat Hospital SINGAPORE

Skyville@Dawson SINGAPORE

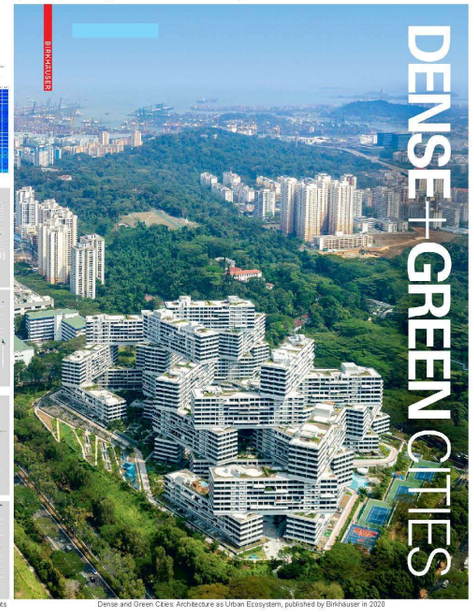
Oasia Downtown SINGAPORE



Economic Analysis of Vegetation on Residential Developments

DENSE AND GREEN CITIES
Architecture as Urban Ecosystem

Innovative building projects in high-density urban environments show that density and sustainability are not necessarily contradictory. In fact, they can be mutually dependent and synergistic. For the past six years, the Dense and Green Cities research project at the Swiss Federal Institute of Technology Zurich (ETHZ), the Singapore University of Technology and Design, and the Singapore-ETH Centre Future Cities Laboratory has explored exemplary urban developments throughout the world that demonstrate possible interactions between 'green' buildings and the city as ecological systems and the many design, environmental, social, and economic benefits the resulting dense and green cities offer. The project has developed innovative methods and tools that allow for dense and green buildings to support higher urban standards of environmental sustainability as well as enhanced urban resilience and liveability and it has resulted in many presentations, exhibitions, and publications including most recently Dense and Green Cities: Architecture as Urban Ecosystem, published by Birkhäuser in 2020 (DOI: https://doi.org/10.1515/9783035615111).

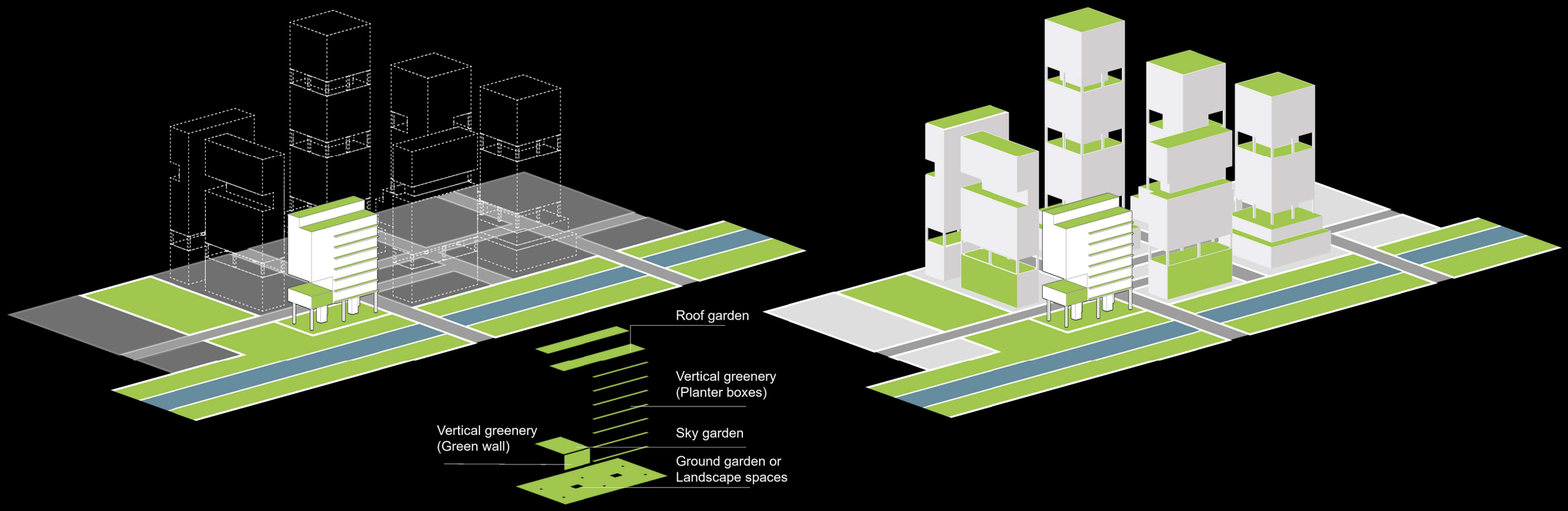


Dense and Green Cities: Architecture as Urban Ecosystem, published by Birkhäuser in 2020

Performative Buildings to Districts

Dense and Green Cities (2020)

- From building scale to urban scale: urban-innovations-and-systems-solutions-approach to planning and design
- Sustainable Integrated Districts (SIDs) as a model for high-density high-liveability future cities
- Potentials of systems solutions by deploying and integrating them at the district scale
- Placed-based approaches to governance arrangements to strengthen local human capacity



Dense and Green Cities

Emerging Models of Integrated Urban Development

- SIDs aim to fully realise the potential of urban innovations and systems solutions by deploying and integrating them at the district scale.
- SIDs serve as a test bed for examining a place-based approach to governance arrangements, with a focus on strengthening local human capacity – through collaboration and mutual learning – among the diverse stakeholders

Singapore, aerial view

Zurich, Switzerland, aerial view

Dense and Green Cities

Emerging Models of Integrated Urban Development

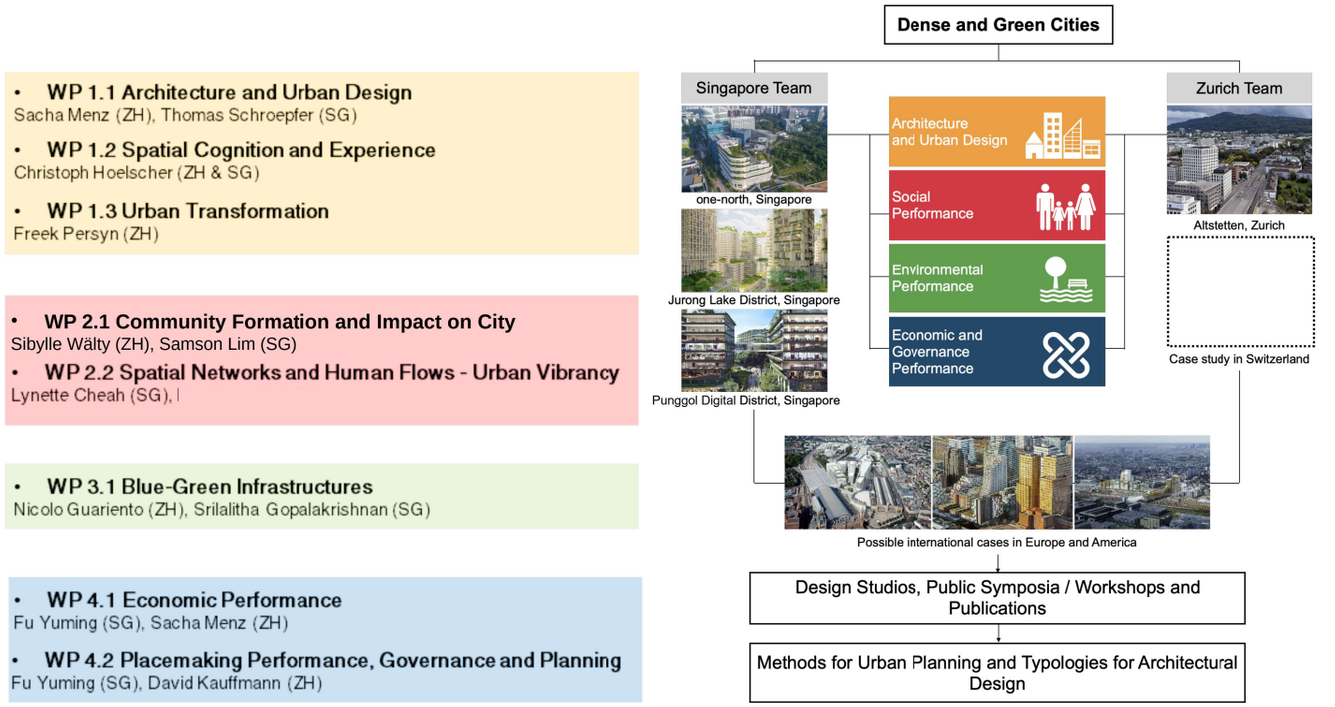
Research Questions

- How can the scaling up of urban innovations and systems solutions lead to resource optimisation and greater synergies at the integrated district as well as the larger city scale?
- What are effective planning guidelines and design strategies for the development of new SIDs, the transformation of existing districts into SIDs and ultimately the development of dense and green cities?
- What implications do different governance arrangements provide on SIDs? To what extent are resource optimisation and functional synergies affected by a specific socio-spatial context framed by the governance system?

Methodological Novelties

- Systems solutions approach to investigate the performance of SIDs
- Context-based research methods for cases in Singapore and Zurich
- Combination of location-based GPS data and real-world observation data
- Integration of analyses and findings toward tangible outcomes

Research Framework



Dense and Green Cities for a Nature – Positive Future

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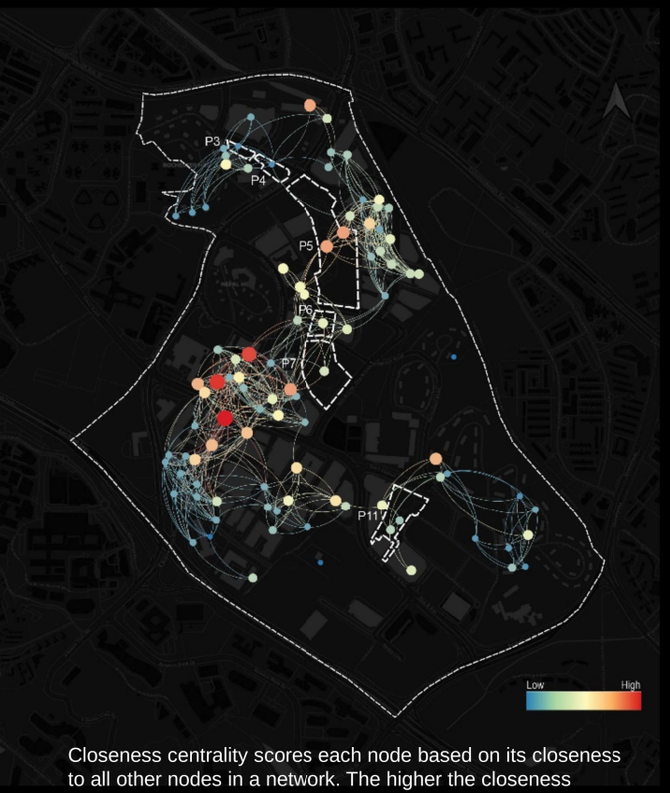
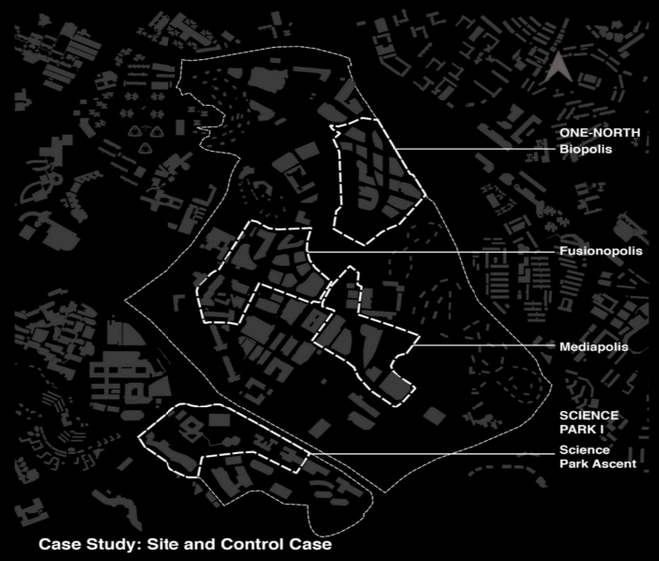
Architecture and Urban Design

Spatial Analysis of Sustainable Integrated Districts

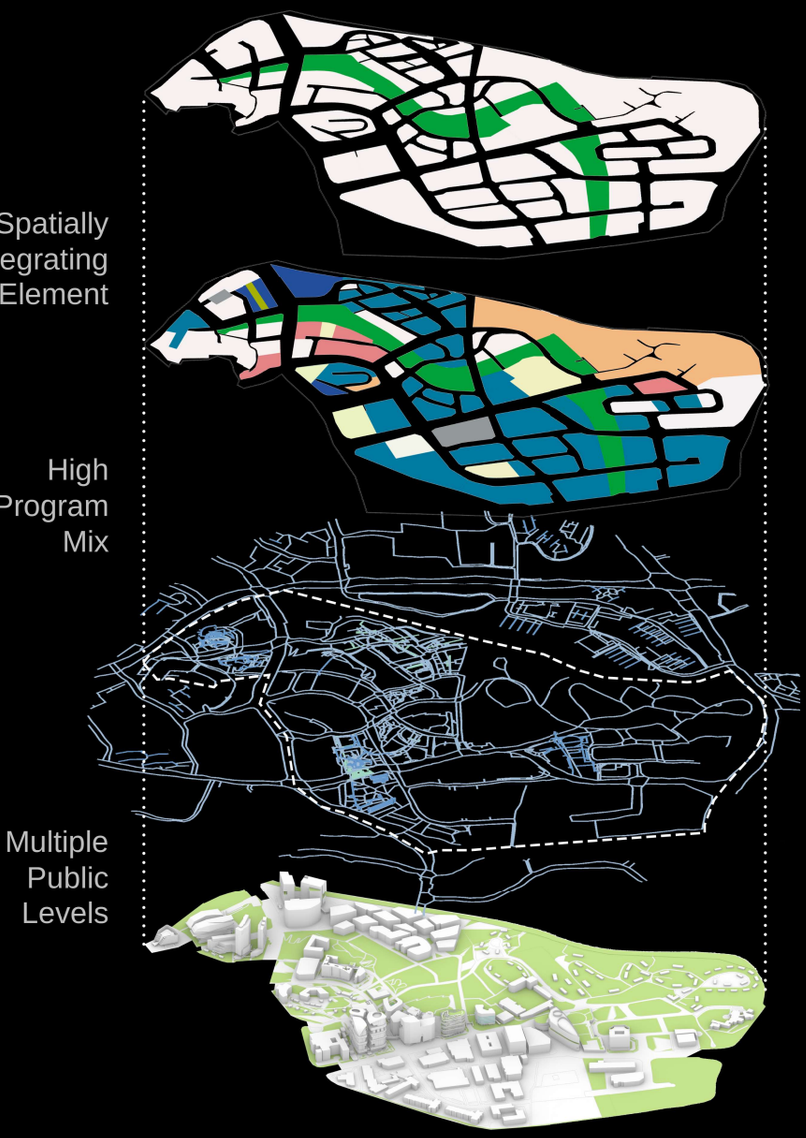
- Did the SID's urban form lead to greater pedestrian flows and activity than in other districts?
- What characteristics did planning and design strategies in SIDs generally share as they relate to pedestrian flows and activity, and their effect on urban vibrancy?
- Were there emerging urban forms that support greater pedestrian flows and activity?



Closeness centrality scores each node based on its closeness to all other nodes in a network. The higher the closeness centrality, the more likely the node is to be visited.



Case Study: Site and Control Case



- *Spatial characteristics of integrated districts*

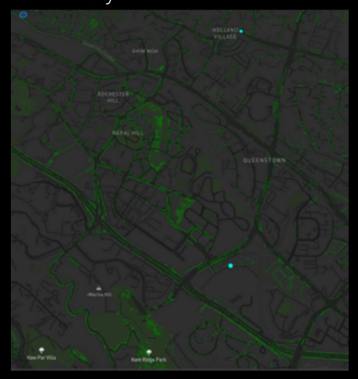
Architecture and Urban Design

Urban Visual-Spatial Analysis

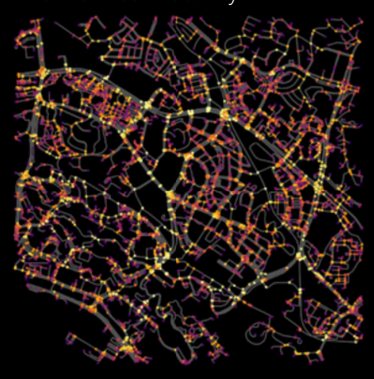
- How the visual environmental context and urban morphology affected the way people inhabited, used, and interacted in public spaces and how urban design features, elements, and experiences affected their usage patterns?

Buildings and walking network

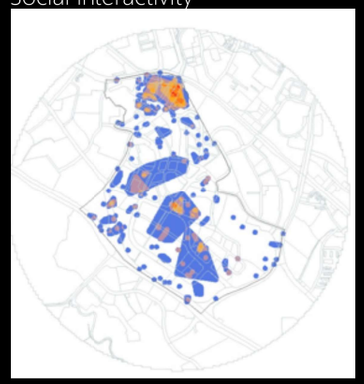
Greenery



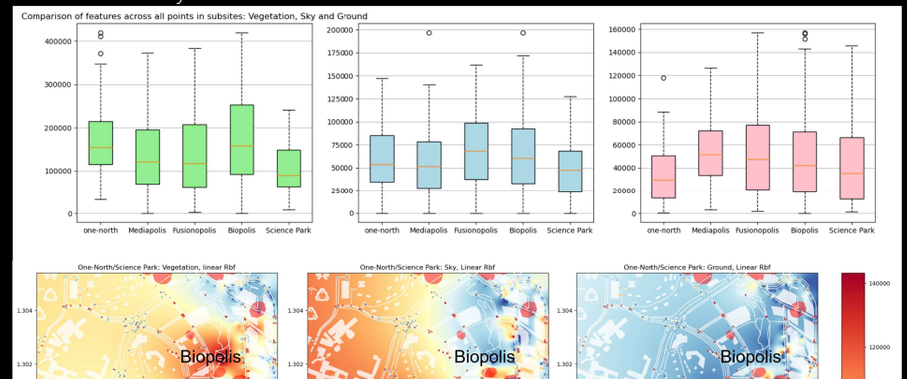
Network connectivity



Social interactivity



Visual analysis



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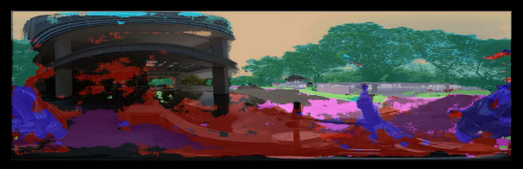
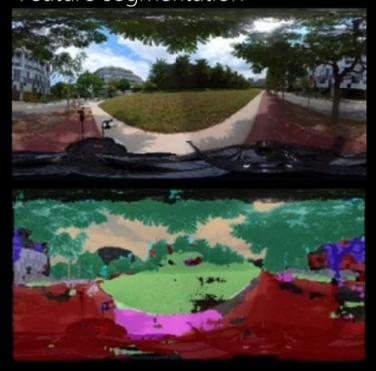
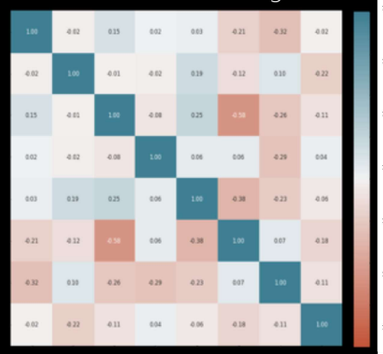


Feature segmentation



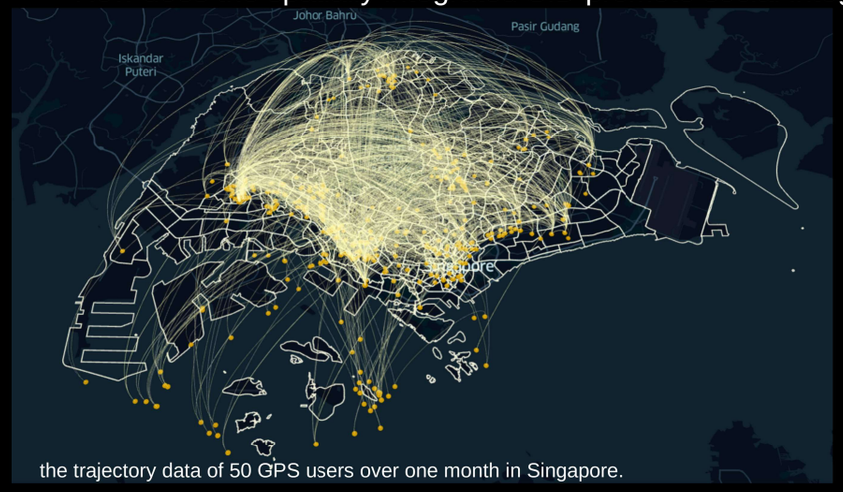
Feature correlation in image sets



Social Performance

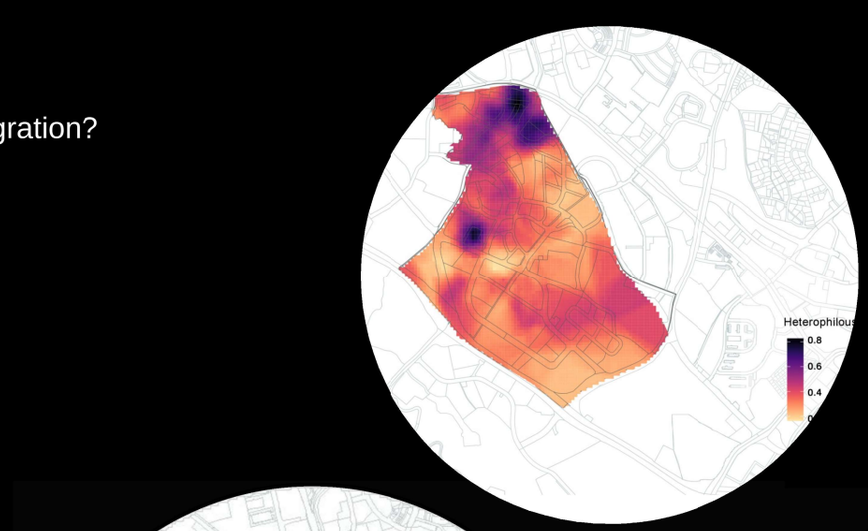
Socio-spatial Integration in SIDs

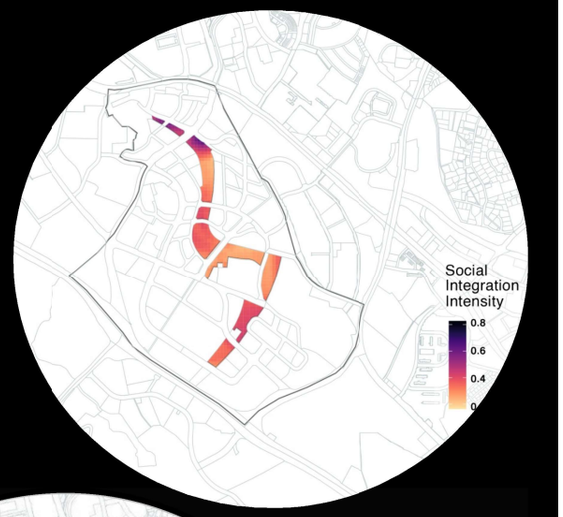
- How does the spatially integrated SID promote social integration?



the trajectory data of 50 GPS users over one month in Singapore.

the trajectory data of 1 GPS users over one month in Singapore.



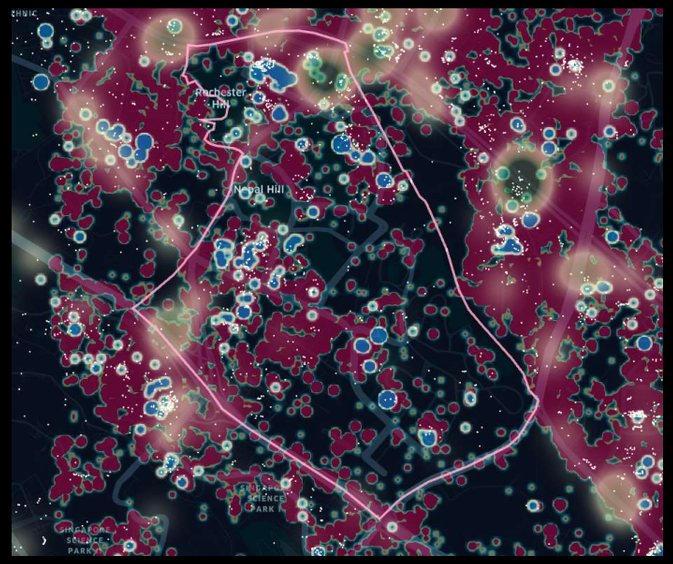


Source: Socio-spatial integration in innovation districts: Singapore's mixed-use experiment

- *Spatial characteristics of integrated districts*
- Community Activity Spaces and Interaction Opportunities

Social Performance

Spatial Networks and Human Flows - Urban Vibrancy of SID’s

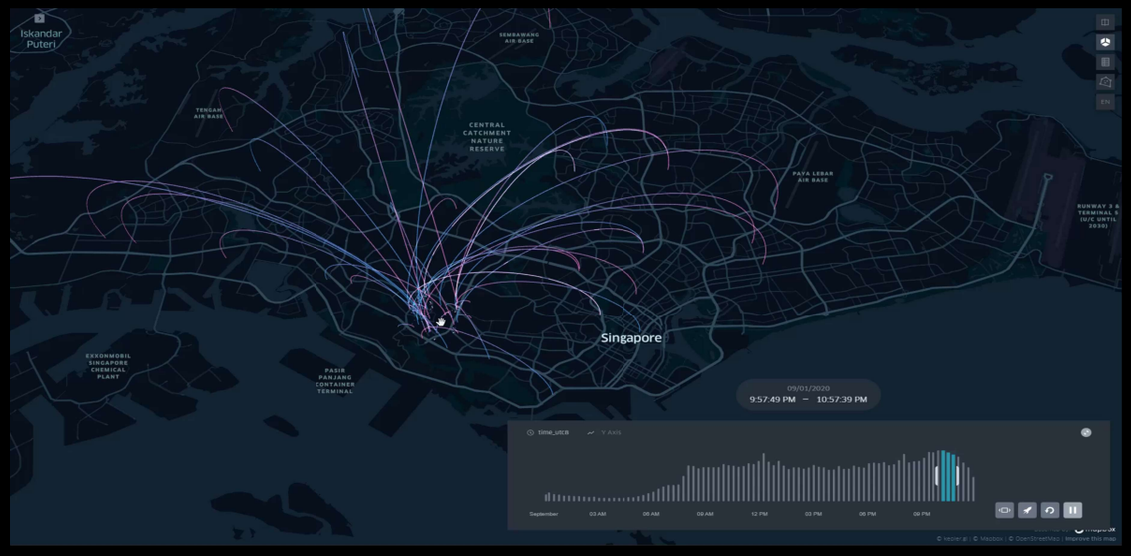


Compiled Map

- Citydata (2020.9.1-2020.9.7)
- Tweets (2018-2022)
- POI (extraction at 2021)
- Bus trips (2021.1 weekday)

one-north: Points of Interest (POI) mapping within the planning area

Observation | temporal pattern of long-distance and short-distance transitions

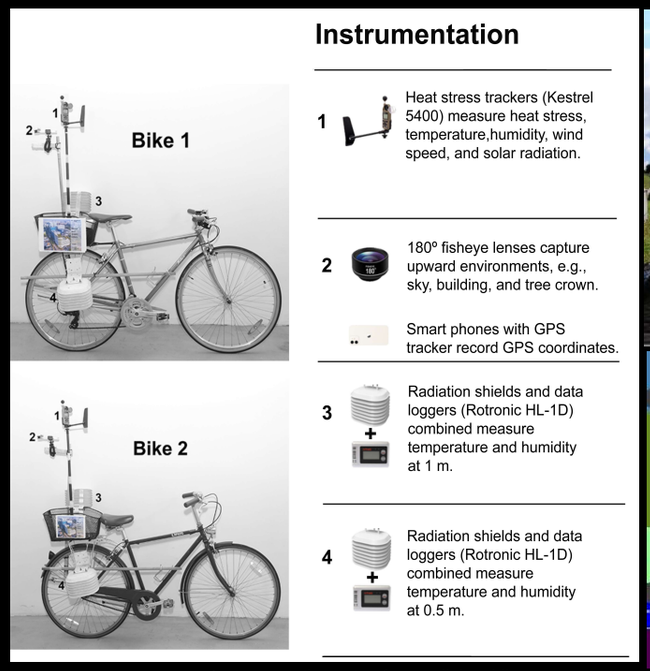


Environmental Performance

Outdoor Thermal Comfort Assessment in SIDs

- Climate change and rapid urbanization worsen outdoor thermal conditions, causing thermal discomfort and heat-related mortality.
- How do SIDs contribute to outdoor thermal comfort?
- Do SIDs provide better cooling services than traditional districts in tropical climates?

Mobile survey



Instrumentation setup for parallel mobile survey

Image Processing

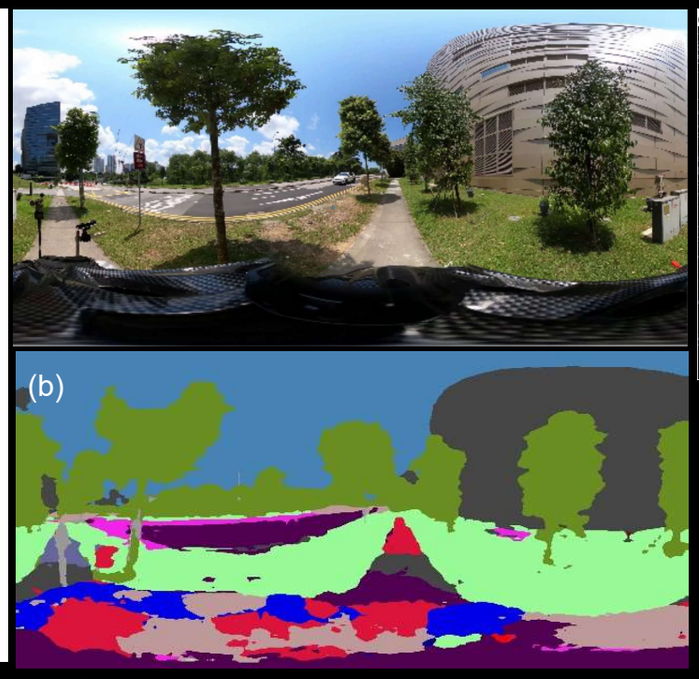
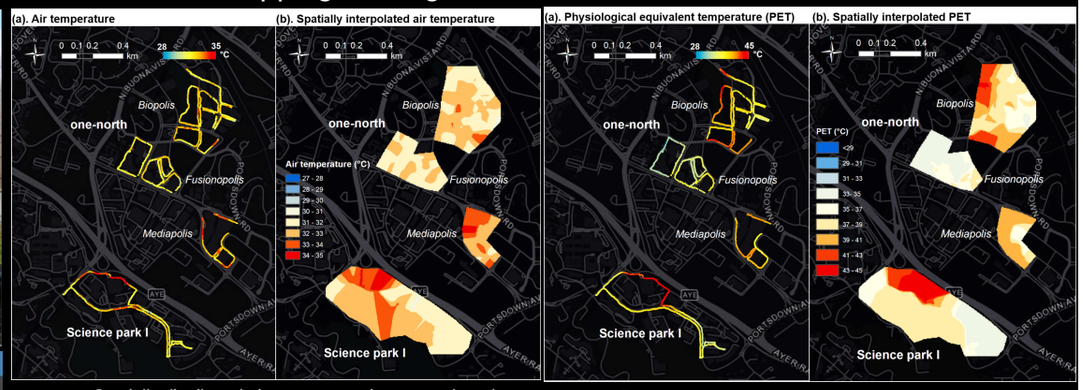


Figure. a) original panoramic street view image, b) semantically segmented image

Urban Heatmapping Findings



Spatially distributed air temperature in one-north and Science park I, a) measured air temperature and b) spatially interpolated air temperature

- one-north, especially in the Biopolis and Fusionopolis subsites, provided cooler air temperature than Science Park I.
- The mean temperature in one-north was 0.3°C lower.
- The percentage of hot weather (air temperature > 33°C) in one-north was 8%, compared to 24% in Science Park I.

Spatially distributed physiological equivalent temperature (PET) in one-north and Science park I, a) calculated PET and b) spatially interpolated PET

- one-north, especially the Fusionopolis subsite, provided more thermal comfort than Science Park I.
- The mean PET (a thermal comfort index) in one-north was 0.8°C lower.
- The percentage of 'very hot' thermal perception in one-north was 1%, significantly lower than 15% in Science Park I.

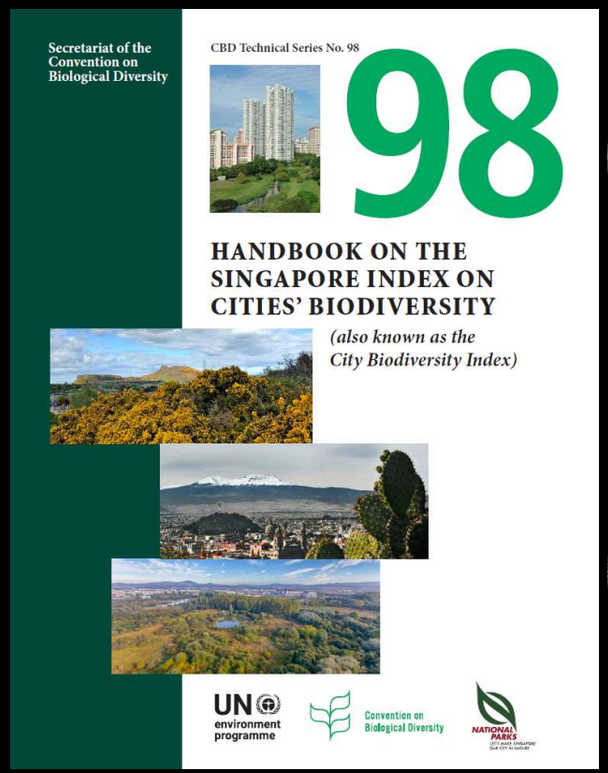
Ecological Performance

Urban Landscape Connectivity in SIDs

- The study investigated how Blue-Green Infrastructure (BGI) in SIDs contributes to increasing ecological connectivity and biodiversity at the district scale.
- Do the district's urban green and blue open spaces improve the overall landscape connectivity for the larger urban context?
- Do the district's urban green and blue open spaces act as key ecological connectors?

Singapore Index (SI) on Cities' Biodiversity

Self-assessment tool to benchmark biodiversity efforts within urban contexts



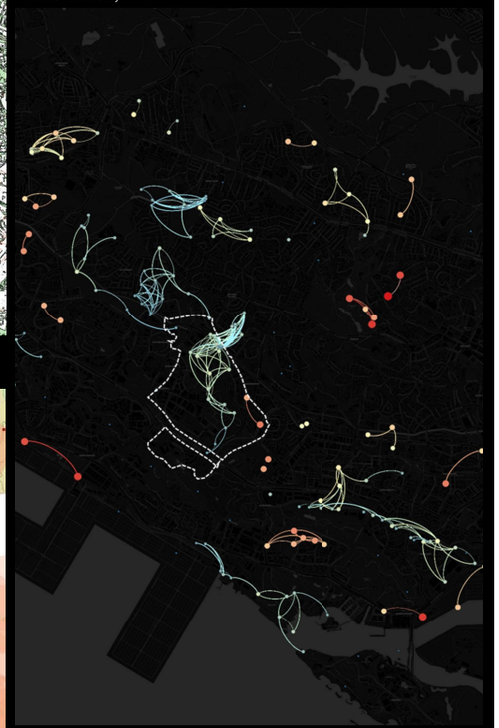
Urban Scale

District Scale

Comparison of habitat provision considering only natural and natural + managed green areas

Map indicating the proximity and accessibility of plots to parks and green spaces within a 400m radius (5-minute walking distance)

Urban Landscape Connectivity Analysis (a) Closeness score within a 5-km radius of one-north;



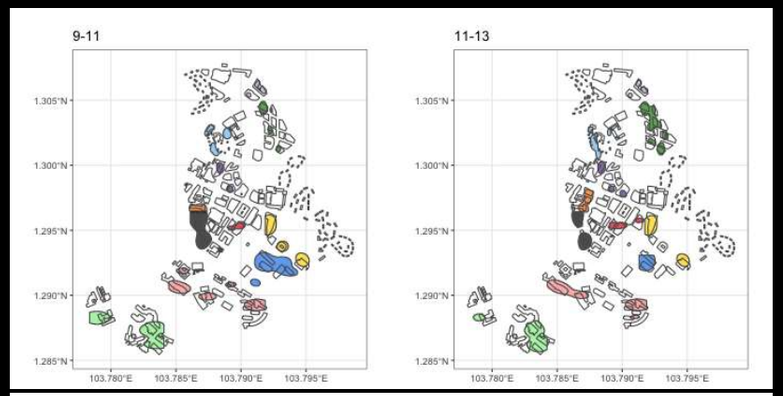
Economic Performance

Socio-economic Integration in SIDs

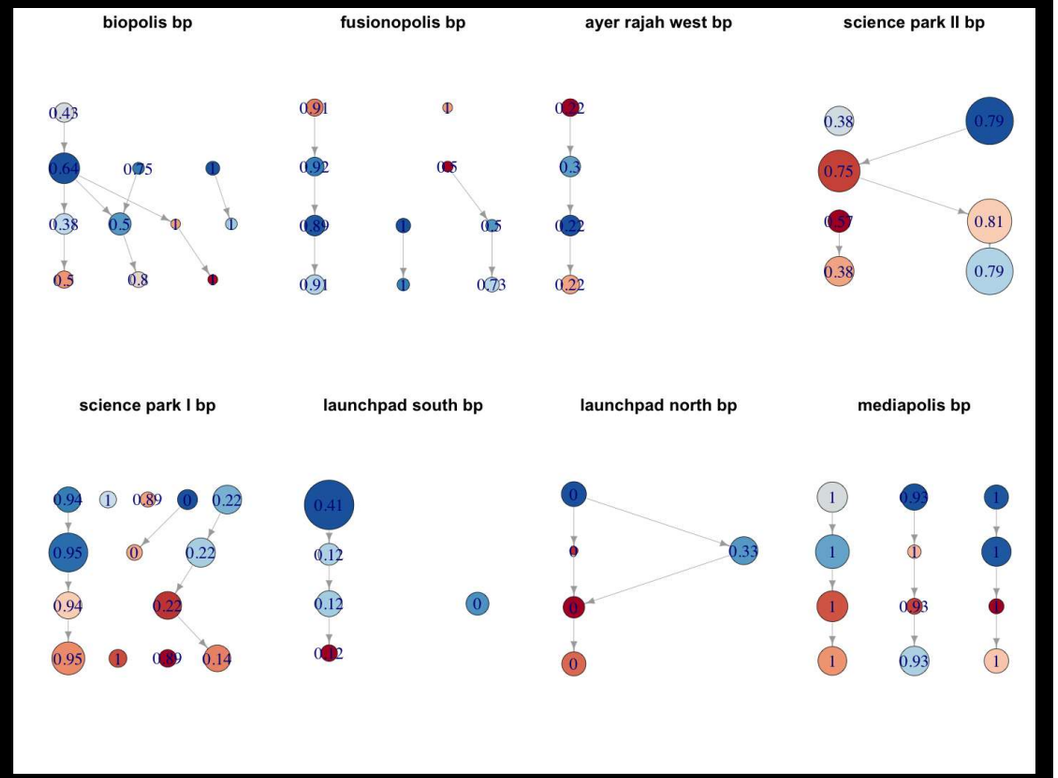
- How does the districts' public realm (or the "living room") support social interactions?
- To evaluate the economic performance of a SID compared to the control sites by examining the relationship between people's mobility and social hotspots and analysing how the demand for face-to-face interaction drives location choice

Plaza space in one-north

Urban spaces within one-north district



Spatiotemporal Hotspot Network Evolution

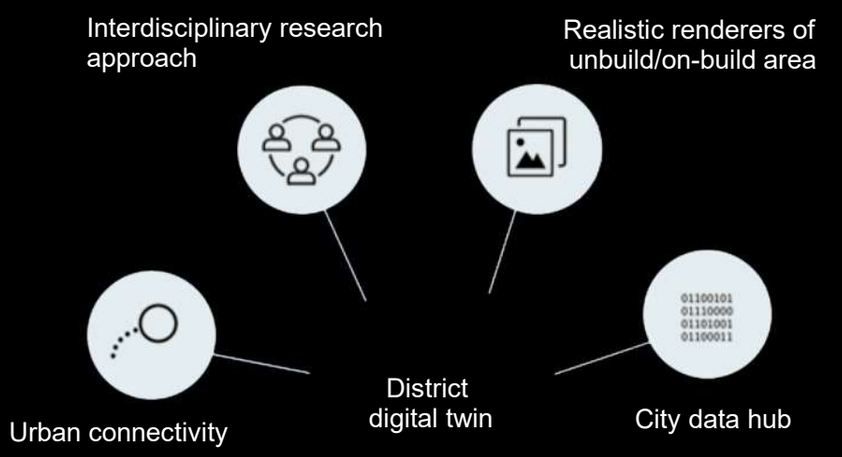


Subsites "living room" signatures

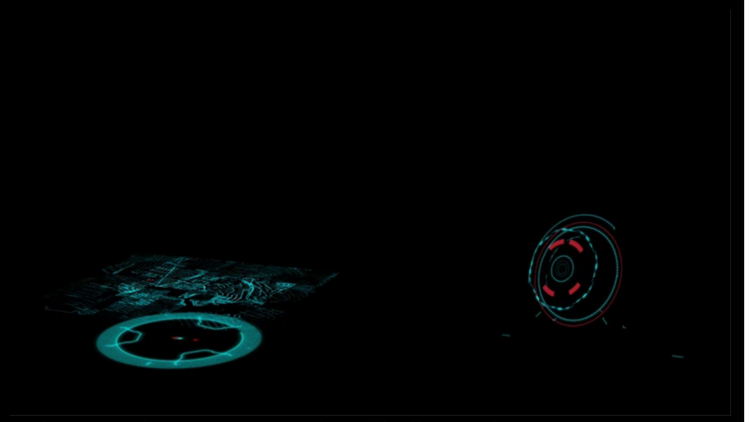
Digital Tools for SIDs

Visualisation Dashboard and Analytical Tool

- Digital twins are used as an effective research tool for an urban scale analysis and future scenario planning



Digital twin of Sustainable integrated district one-north park



Virtual on site experience for VR, Computer vision and visual cognition analysis

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Emerging Models of Integrated Urban Development

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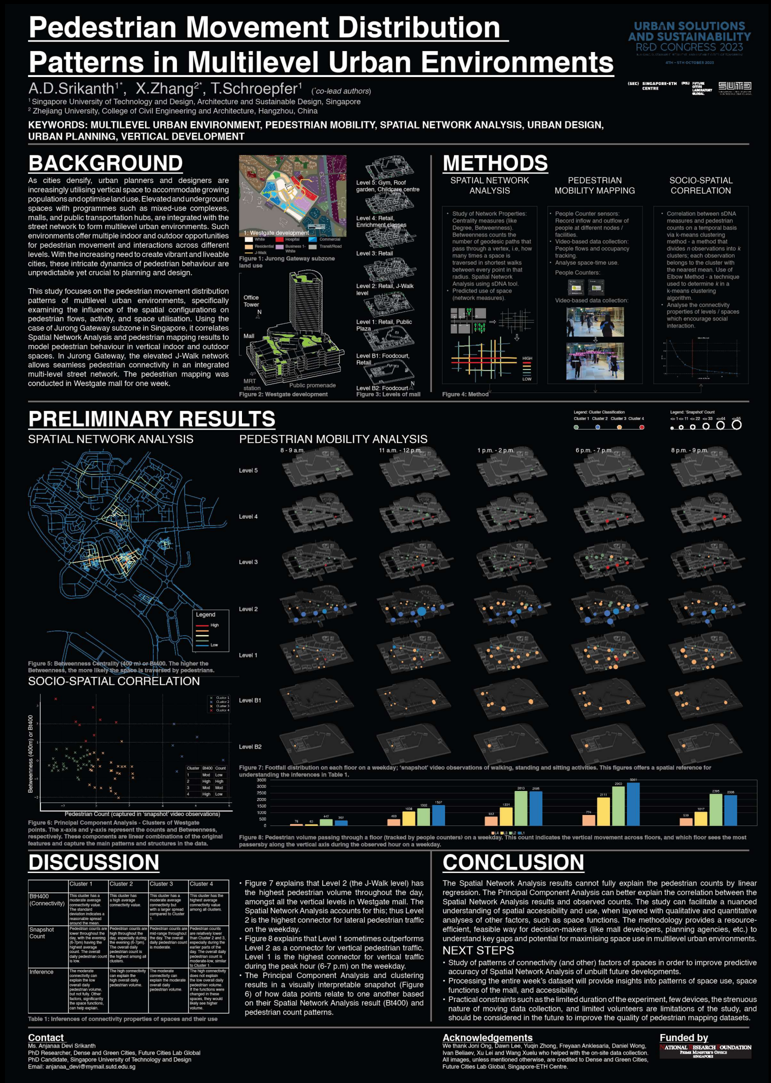
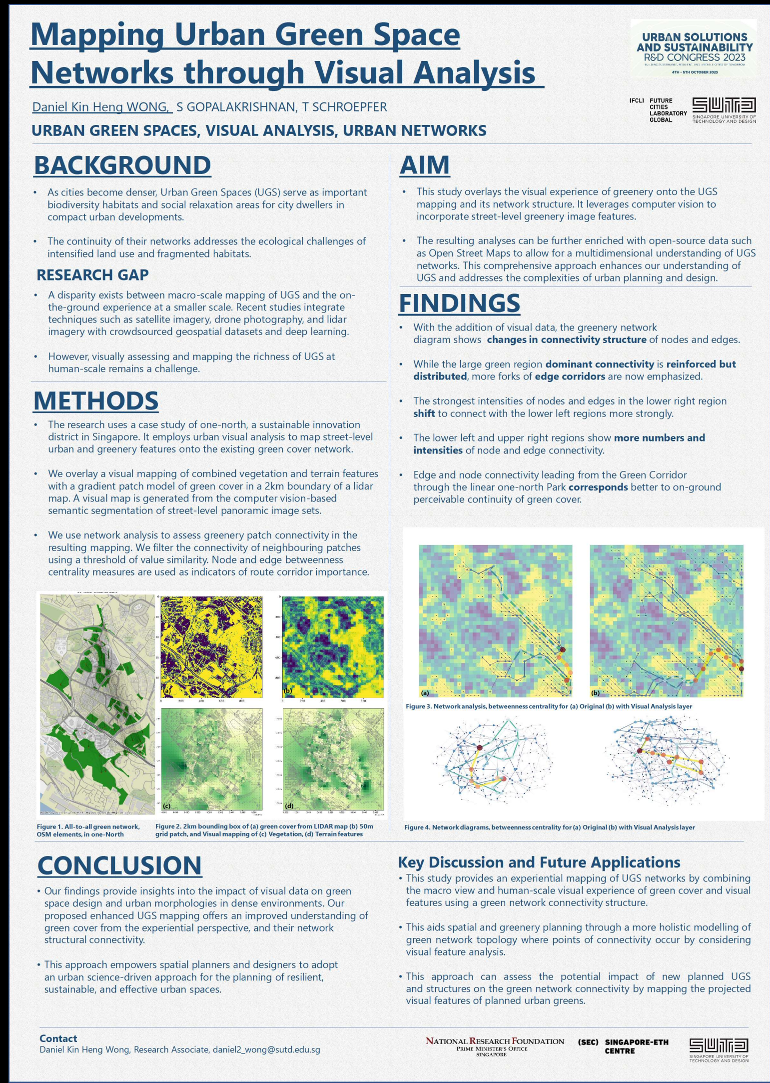
Dense and Green Cities for a Nature – Positive Future

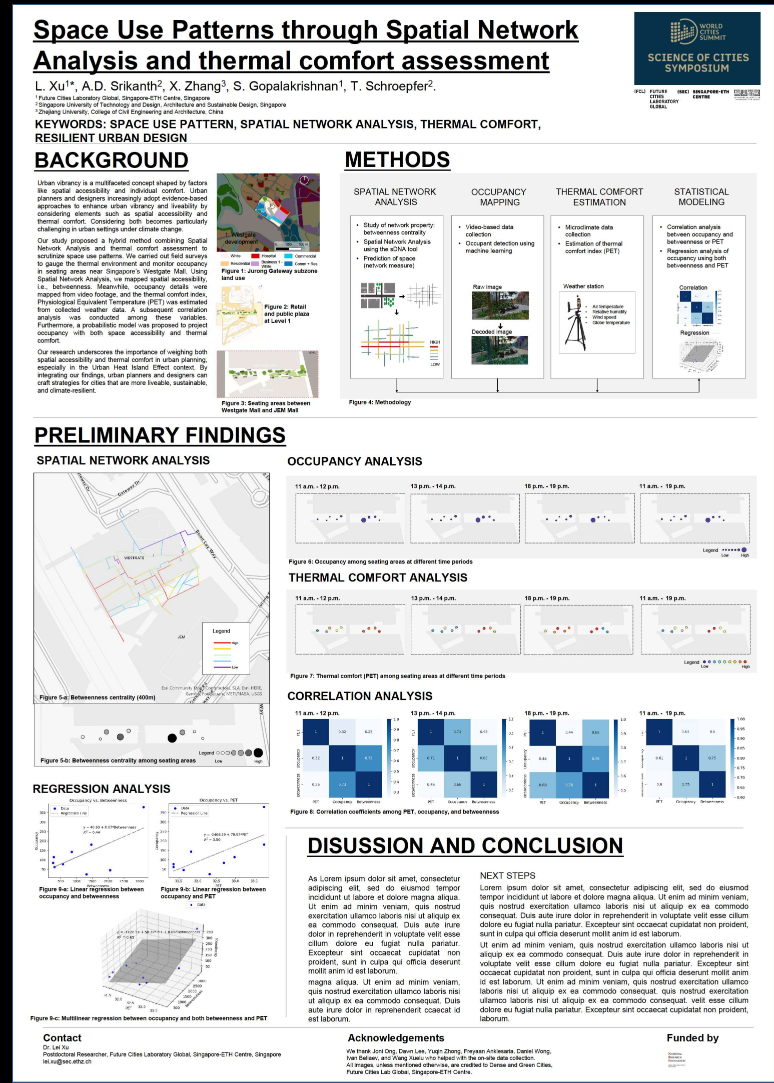
(FCL) FUTURE CITIES LABORATORY GLOBAL

Science of Cities Symposium 2023

Poster presentations at the SoC Symposium 2023







Science of Cities Symposium 2023

Poster presentations at the SoC Symposium 2023

Emergent Social Hotspots

I. Orlenko, L. Cheah, Y. Fu, T. Schroepfer

Social Dynamics, Emergent Spatial Organisation, Complexity

(FCL) FUTURE CITIES LABORATORY

BACKGROUND

- Social vibrancy entails diverse social interactions and networks, which, in well-planned places, often sort themselves into social hotspots of various sizes according to the functionality and network centrality of the hotspots.
- Many open complex systems, such as cities, have a size distribution that can be described by a power law.

RESEARCH GAP

Few studies have sought to empirically quantify social hotspots and their emergent spatial order in urban districts. Such empirical facts are crucial for motivating and testing theories of urban vibrancy.

AIM

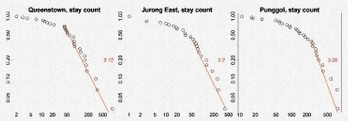
We use an urban science approach to examine the self-organization of social hotspots in the urban context of three planning areas of Singapore.

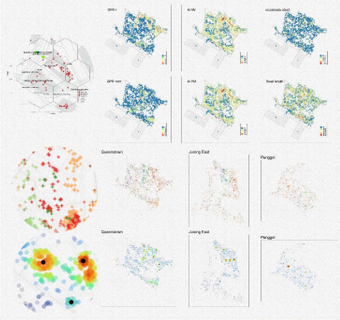
METHODS

- GPS mobile phone data, POIs -> PAM spatial clustering
- Transport infrastructure measures -> PCA

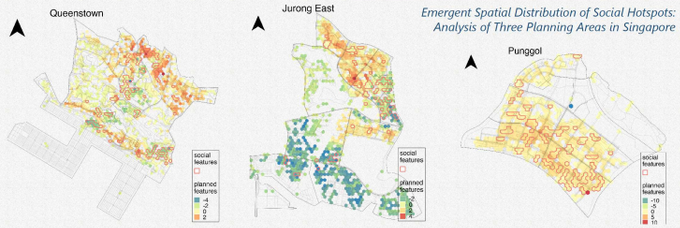
FINDINGS

The system of hotspots in each district has an approximate power-law order. The size dispersion of hotspots appears bigger in more central districts.





Emergent Spatial Distribution of Social Hotspots: Analysis of Three Planning Areas in Singapore



CONCLUSIONS

- Urban science seeks to identify essential phenomena at different scales that emerge from network interactions of people and businesses in complex urban systems.
- GPS data opens an avenue for applying urban science to the study of social vibrancy in urban districts.
- Our preliminary findings suggest the potential for this new avenue to uncover the influence of urban and planning context on social vibrancy phenomena.

Future applications

- Further insights into urban vibrancy can be gained by examining the scaling properties of hotspots with respect to various behaviors and attributes of their visitors, such as visit frequency, distance from home, and the mix of within-district vs. outside visitors.
- Cross-district comparison of hotspot size dispersion and scaling can reveal how social vibrancy of a district is influenced by its social, spatial, and land-use context.

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(SEC) SINGAPORE-ETH CENTRE

Designing for Diversity: The Impact of Visual Environment

Tongchaoran Gao, Daniel Kin Heng Wong, Prof. Thomas Schroepfer

Visual environment, Computer vision, Social integration

(FCL) FUTURE CITIES LABORATORY GLOBAL (SEC) SINGAPORE-ETH CENTRE

BACKGROUND

High-density urban areas can enrich lives while also inducing social withdrawal, which negatively affects cross-cultural interactions and exacerbates social segregation. Recognizing the crucial role of well-designed public spaces in fostering healthier lifestyles and social engagement, this study aims to examine how spatial features within these areas contribute to social integration. The research is centered on **one-north**, a sustainable innovation district in Singapore, where effective social integration is key to attracting and retaining talented workers.

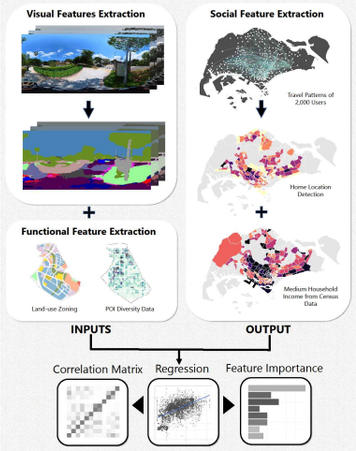
RESEARCH GAP

While the visual environment is a key aspect of spatial features, its impact on social integration is not well-studied, especially at the granularity of street-level data.

AIM

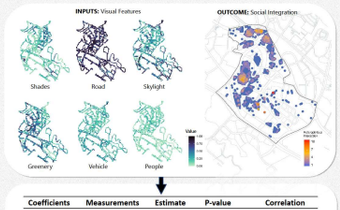
The objective is to integrate social integration considerations into urban design by investigating the correlation between the visual environment of public spaces and the level of social integration therein.

METHODS



Employing a GeoAI methodology, the study undertakes three main steps. First, it analyzes 5,800 street view images from one-north using the SegFormer computer vision model to extract visual features. Second, it utilizes the travel patterns of 2,000 anonymous GPS users to extract social features. Third, it gleans functional features from Point of Interest (POI) data and Master Plan zoning information. These datasets are then synthesized in a regression model to assess the impact of visual environments on social integration.

FINDINGS



Coefficients	Measurements	Estimate	P-value	Correlation
Shades		1.00	2.2e-4***	
Road		-1.44	9.4e-12***	
Skylight		0.96	4.1e-3**	
Greenery		1.78	1.88e-12***	
Vehicle		-1.54	0.07 .	
People		0.91	0.54	
POI		0.03	1.88e-14***	

The regression analysis reveals a significant impact of visual features on social integration, evidenced by an R2 value of 0.31. Positive contributors to social integration include shades, skylight, and greenery, while roads and vehicles negatively affect it.

CONCLUSION/S

In assessing the influence of visual environment on social integration in high-density locales, this study, centered on one-north in Singapore, utilized GeoAI techniques. It determined that aspects such as shades, skylight, and greenery enhance social integration, whereas roads and vehicles detract from it.

<Future applications>

The methodology and findings can be adapted for evaluations in different urban settings, further refining our understanding of how visual elements contribute to the social fabric of a community.

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