Master of Science in Urban Science, Policy & Planning

Graduating Class of 2026

Master Research Project

A Compilation of Students' Posters

SINGAPORE UNIVERSITY OF TECHNOLOGY AND DESIGN

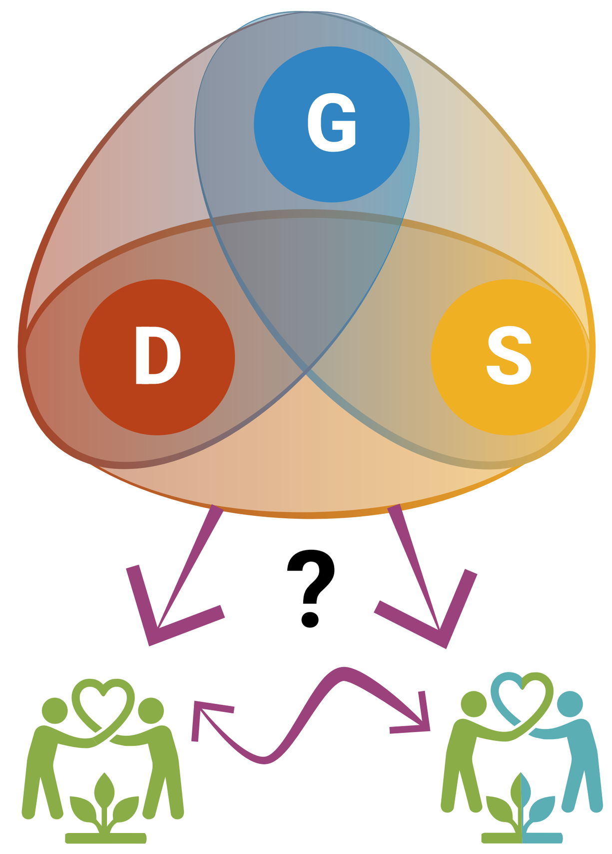
Lee Kuan Yew Centre for Innovative Cities

Contents

Growing Together

Understanding Community Gardens as Social Infrastructure in Singapore's Public Housing Estates

How do physical design, governance models and social programming practices of community gardens together shape social cohesion in Singapore's public housing estates?



Community Gardens (CGs) in Singapore are expected to deliver both **horticultural and social cohesion (SC) outcomes**.

NParks' Community in Bloom (CIB) programme, running since 2005, supports 2,000+ community gardens nationwide, positioned as **hubs for community bonding**.

Most HDB estate gardens are volunteer-run, overseen by Resident Networks (RNs) under the People's Association (PA), which names **social cohesion as a key objective**.

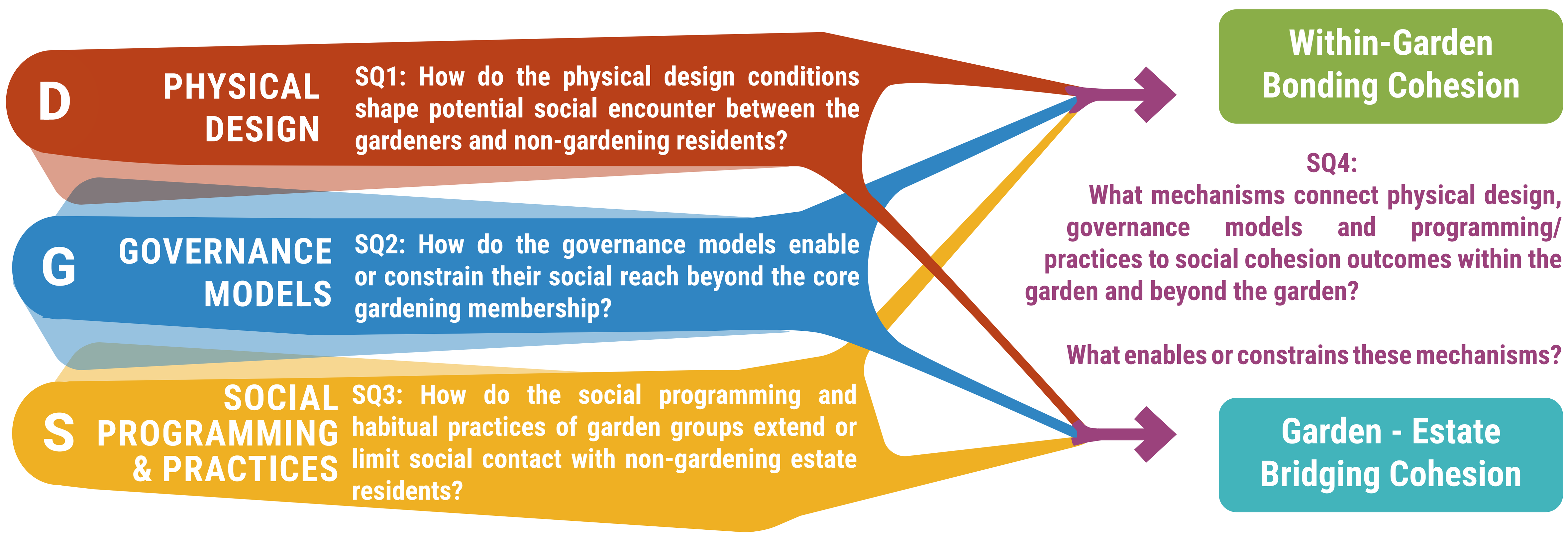
Whether and how these gardens actually function as social infrastructure — for both gardening members and the wider non-gardening estate community — remains unclear.

Prior literature understands social cohesion by independently focusing on the garden's physical design or governance or its social programming conditions within the garden or with the estate community.

This **study's contribution**: identifies the **interface conditions** – the combinations of design, governance and programming that together enable or constrain social cohesion in established HDB estate gardens.

CIB - **CGs in Tampines** are representative of the most prevalent CG type in SG's HDB estates : established, ageing gardens.

4 diverse CGs with variations across the D & G conditions were purposively selected as case studies.



MIXED METHODS STUDY - QUALITATIVE DOMINANT

The mechanisms that shape SC are experiential and relational — best captured in participants' own accounts. 24 Semi-structured interviews with gardeners and governance actors anchor this research design to capture bonding and bridging mechanisms firsthand; cohesion is measured via separate surveys for gardener reporting within-garden & resident reporting for garden-estate bridging with other streams triangulated for corroboration.

#1 INDICATOR IDENTIFICATION
literature reviews

#2 MULTIPLE DATA STREAMS

01 SEMI- STRUCTURED INTERVIEWS [n=24]
first hand accounts followed by hybrid deductive-inductive coding

PHYSICAL CONDITIONS	GOVERNANCE CONDITIONS	SOCIAL PROGRAMMING CONDITIONS	SC WITHIN-GARDEN	SC GARDEN-ESTATE
D	G	S		
D-PhysPermeability D-SocialSpaces D-CoLocation D-Legibility D-AestheticQuality	G-DecisionStructure G-InclusivityAccess G-Responsiveness G-ResourceMobilisation G-RuleClarity	S-Organised Activities S-HabitualMaintenance S-FrequencyConsistency S-PublicisationReach S-LanguageInclusivity	**bonding cohesion:** depth among gardening group = friendship + mutual help + trust	**bridging cohesion:** meaningful relationship formation through the garden between gardening group and residents
(Wood & Giles-Corti 2008; Aelbrecht & Stevens 2023; Lerstrup & Refshauge 2019).	Sia et al. (2023)	Jennings et al. (2016) Kingsley et al. (2009)	Veen et al. (2016)	Forrest & Kearns (2001)

01 PHYSICAL AUDIT [n=4]
documenting what exists

6 physical indicators = openness composite

05 SOCIAL MEDIA ANALYSIS [n=4]

03 SURVEY [n=145]
how do participants self-report outcomes?

[A] GARDENER SURVEY

- Gardeners Perception of Physical, Governance and Social Programming Conditions Within the Garden
- Gardeners Perception of Physical, Governance and Social Programming Conditions that expand garden's social reach

[B] NON-GARDENER SURVEY

- Residents Perception of Physical, Governance and Social Programming Conditions that expand or act as barriers

"60% of survey respondents cited a lack of social programming categories as the primary barrier to join the garden" - Survey B Analysis

Likert Scale (1-5) direction
- I have built trust with my fellow gardeners
- I have helped / been helped outside of garden
- I have atleast one genuine friend in the garden

[A] GARDENER SURVEY [n=26]

Likert Scale (1-5) means
- Neighbours connected through the garden are people I would not have met otherwise
- I have gotten to know my neighbours better through this garden

[B] NON-GARDENER SURVEY [n=119]

04 FIELD OBSERVATION [n=19]
what actually happens?

spatial behaviour	governance behaviour	social practices behaviour + cross-group contact	observed episodes	observed episodes

#3 SYNTHESIS
data convergence

PER-GARDEN SYNTHESIS
- mechanisms identified via interviews + linked with associated SC scale
- traced to D, G, S conditions (whether single or interface)
- triangulated across data stream for condition

CROSS-GARDEN SYNTHESIS

06 DOCUMENT ANALYSIS [n=8]

#4 SQ1 + SQ2 + SQ3 + SQ4 FINDINGS - - - ● #5 MRQ FINDING - - - ● #6 RECOMMENDATIONS

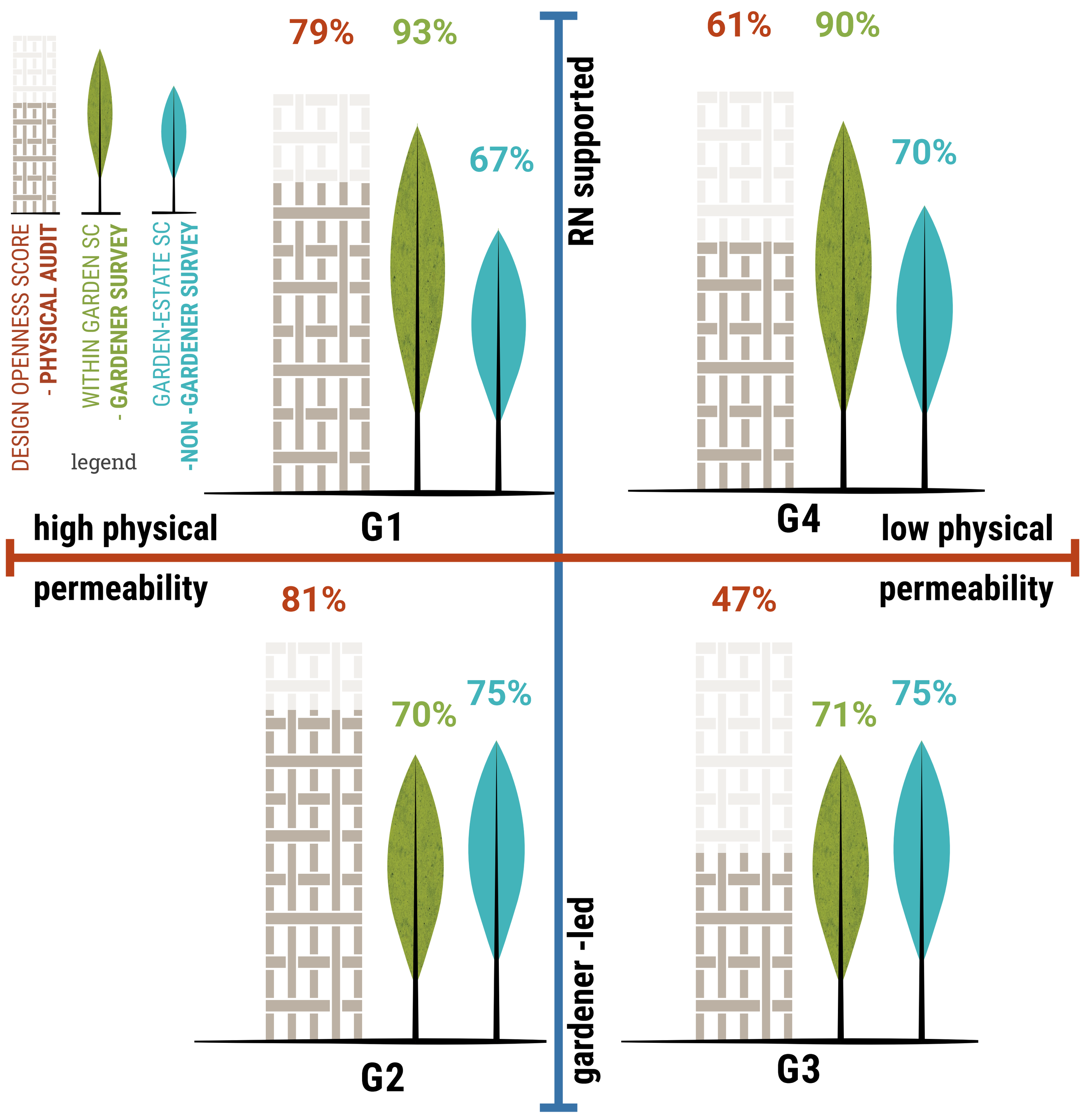
Research Team: Apoorva Madhusudan, Lim Shu Ling, Nidhishree Kumar, Youvara David

Supervisor: Dr. Yunjing Li Jennifer

#5 MAIN RQ FINDINGS

Social Cohesion outcomes for established community gardens in SG's HDB estates vary across scales and are shaped by parallel - independent mechanisms. Governance conditions can strengthen within-garden bonding outcomes and amplify estate-bridging cohesion.

SOCIAL COHESION FINDINGS

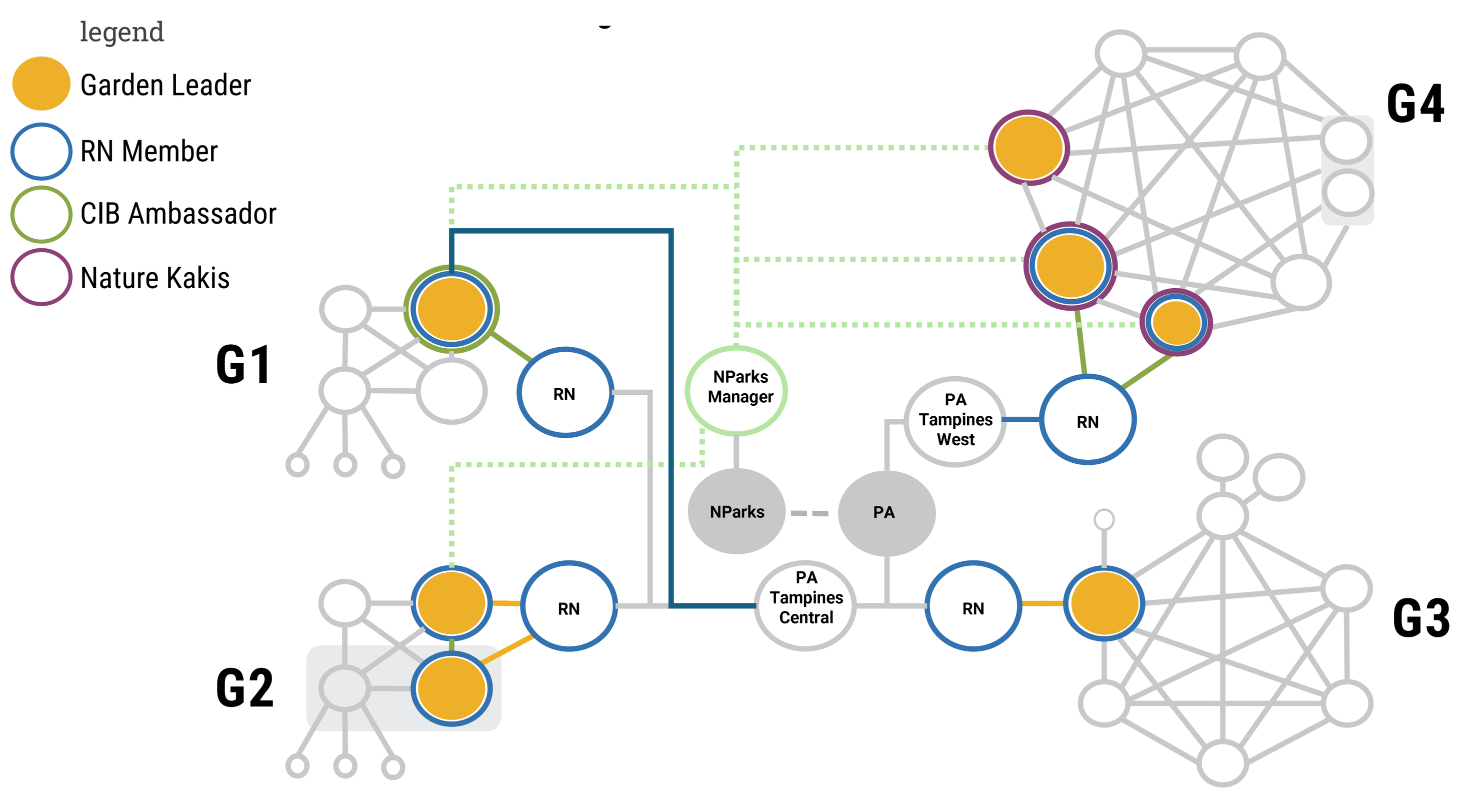


SC outcomes at both scales vary across the 4 gardens and not shaped by physical conditions alone.

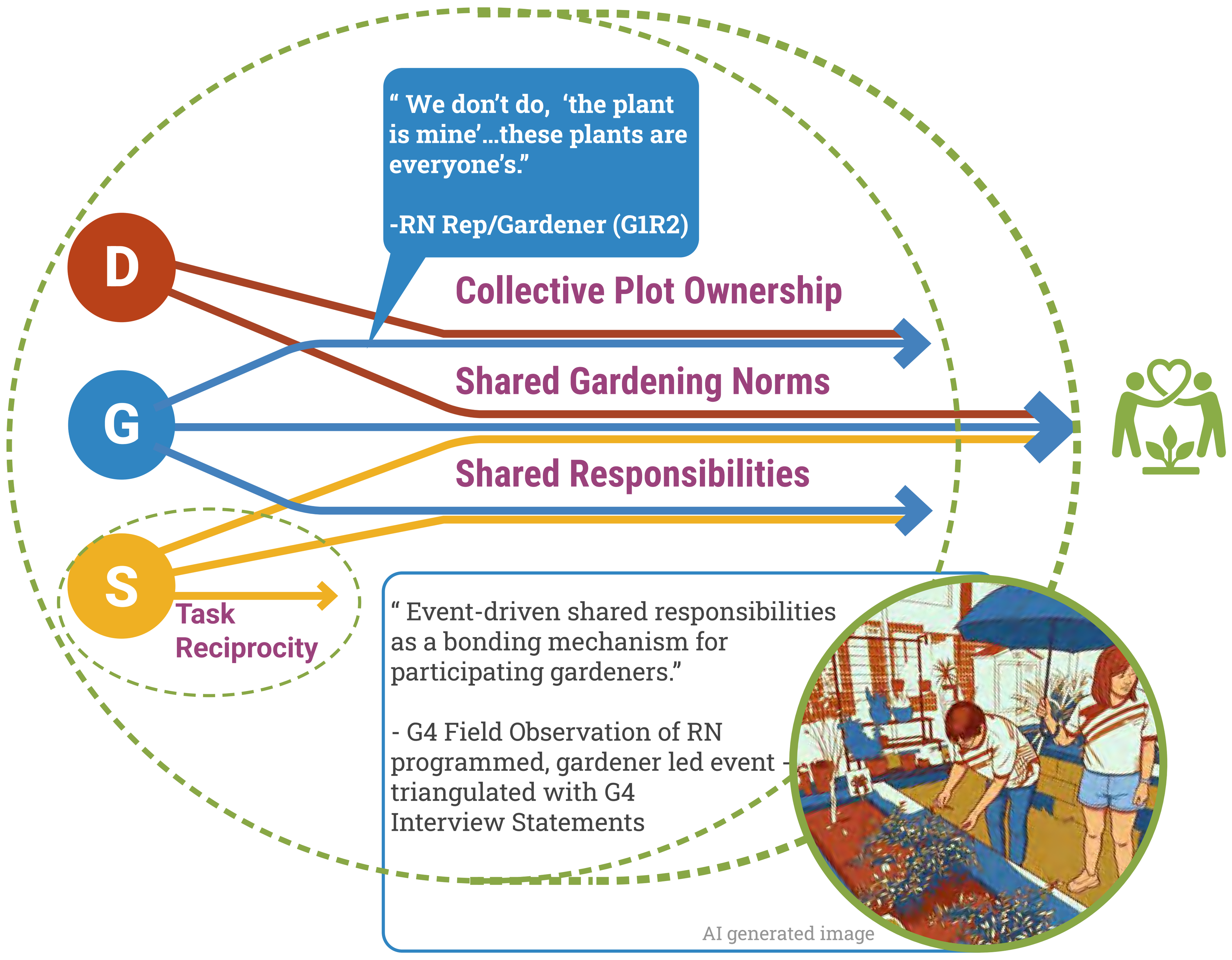
GARDEN GOVERNANCE ACTOR - NETWORK

Garden Leaders - most **direct influence on the within-garden cohesion outcomes**, setting into practice the garden collective's social goals, occupying a mediating role between the gardeners and the RN.

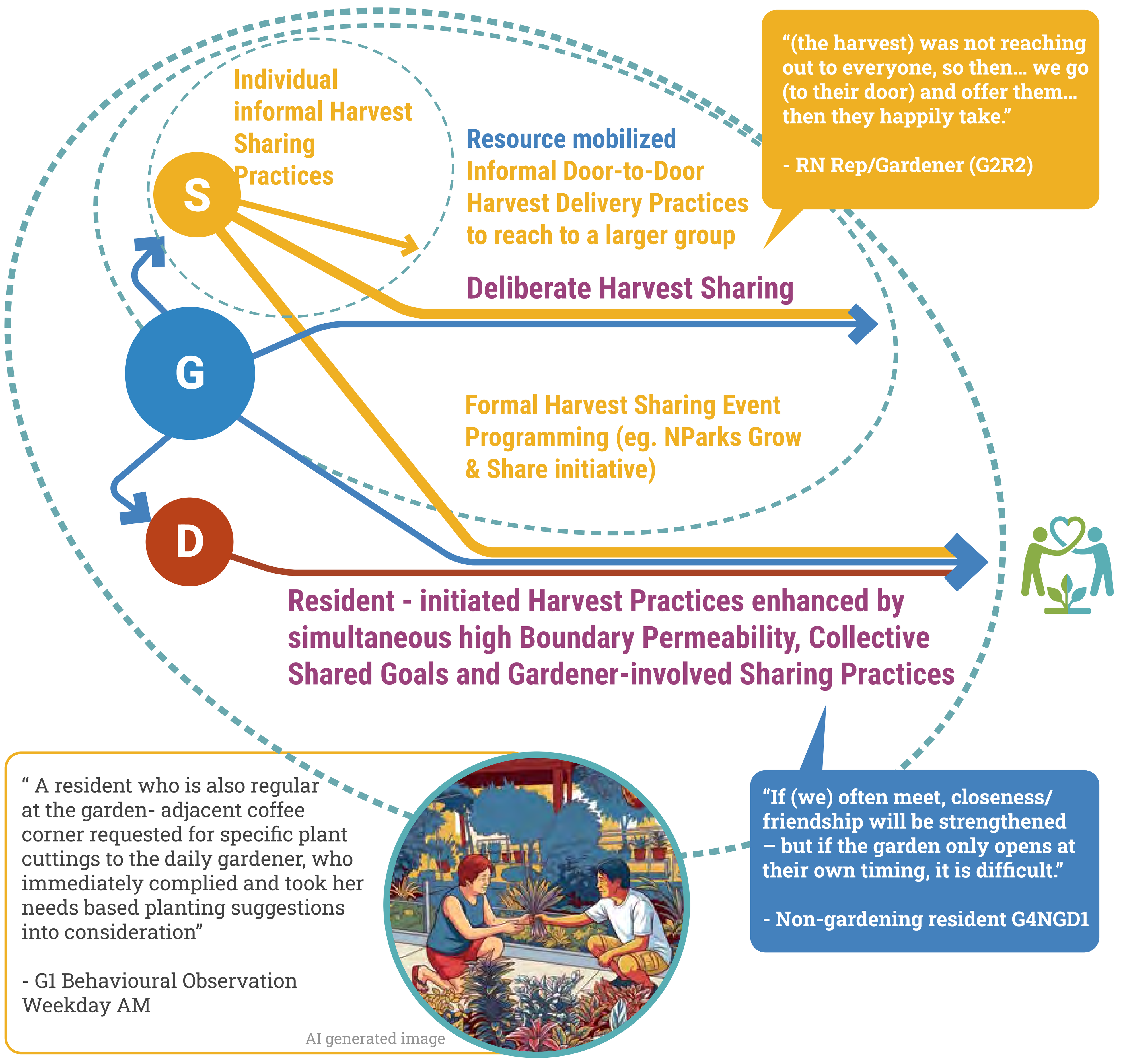
Currently, they rely on their personal connections or mediate through the volunteer-led RN to tap into the institutional resources needed to amplify the garden-estate bridging cohesion.



Within-garden bonding cohesion is strengthened by governance via collective garden policies that drives the shared task practices through which gardeners form genuine bonds with each other.



Garden-to-estate bridging cohesion is shaped primarily by the social practices of deliberate harvest sharing, strengthened by physical permeability with governance acting as an amplifying condition that extends the garden's social reach to estate residents.



#6 RECOMMENDATIONS

Strengthen garden leadership capacity at both individual level (e.g. NACLI courses building people-centric mediation skills) and management-team level (e.g. leadership rotation, upfront succession planning) to sustain within-garden bonding.

Encourage informal harvest sharing through easy-to-harvest planting recommendations and funding support, backed by RN-assisted distribution, while improving garden legibility via physical signage and social media to strengthen garden-estate bridging cohesion.

LIMITATIONS AND SCOPE FOR FUTURE RESEARCH

This study is **limited to ground-level CIB gardens** in established estates conducted in 2 months. With 4 gardens and limited survey sampling size, findings are primarily directional.

Future Directions: Apply the framework developed here (two cohesion scales, mechanisms and three conditions) to **other garden types** (e.g. MSCP rooftop gardens) & other neighbourhood social infra with larger sample bases & longtitudinal tracking to check which **findings transfer across contexts.**

Team BCRS. Returning to Recycle

RETURNING TO RECYCLE

OPTIMISING RECYCLING BEHAVIOUR THROUGH A SOCIO-SPATIAL ANALYSIS OF SINGAPORE'S REVERSE VENDING MACHINES (RVMs) DURING THE EARLY IMPLEMENTATION OF THE BEVERAGE CONTAINER RETURN SCHEME (BCRS)

*BY **WONG** JIA XUE CLIFTON, **CHUA** HUI JIN TRACEY, STEFAN SAMUEL RAJA **PARDEDE** & OWEN **CHIKOTI***

1 BACKGROUND

Singapore's Beverage Container Return Scheme (BCRS) was introduced on 1 April 2026 to improve the recovery of plastic and metal beverage containers through nationwide network of Reverse Vending Machines (RVMs) to facilitate refund of the 10-cent deposit collected upon payment of beverage drinks.

As the scheme is in its early implementation phase (Phase 1), understanding how RVM accessibility and socio-spatial factors influence public participation is critical for informing future RVM network optimisation.

This study adopts a mixed-methods socio-spatial approach to evaluate RVM accessibility, recycling behaviour and identify planning strategies for future research and Phase 2 optimisation.

2 LITERATURE REVIEW

Deposit Return Schemes (DRSs) have demonstrated high recovery rates internationally. Germany, for example, achieves approximately 98% return of eligible beverage containers (TOMRA, 2025) , demonstrating the effectiveness of mature DRS implementation.

Singapore's 2019 Zero Waste Masterplan laid the foundation for initiatives such as the 'Recycle N Save' scheme and the more recent nationwide implementation of BCRS (NEA, 2022; NEA, 2026) to improve recycling efforts.

As the scheme is in its early implementation phase, there is an opportunity to evaluate how city-scale RVM accessibility and demographic factors influence participation to inform evidence-based RVM deployment and support Singapore's progress towards higher container return rates.

3 RESEARCH QUESTIONS & METHODOLOGY FRAMEWORK

HOW CAN SINGAPORE DESIGN ITS WAY TOWARDS 98%?

SUB-RESEARCH QNS (SRQ)	SRQ1: How accessible is the current RVM network?	SRQ2: How do socio-spatial factors influence RVM Usage in BCRS Phase 1?	SRQ3: How to optimise BCRS Phase 2?
	Insights from: GIS	Insights from: GIS + Survey + Observation	Insights from: GIS + Survey + Observation + Interviews

METHODS AND DATA SOURCES

1 GIS Analysis
Assess accessibility & spatial context
- Maps RVM distribution, catchments and walkability
- Identifies spatial gaps and priority areas for study

Spatial data obtained from open source sites (data.gov.sg) to conduct islandwide, planning-level and neighbourhood-level analysis

2 Online Survey
Perceptions & self-reported behaviour
- Quantifies recycling behaviour for downstream analysis

n = 171 valid respondents Recruited through *SGResearchLobang* Telegram channel; after geocoding and postal code validation

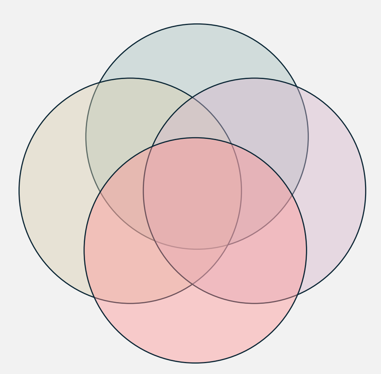
3 On-site Observations
Actual behaviour @ RVM sites
- Observes real-world usage pattens
- Verifies or challenges self-reported responses in survey

6 regions, 26 sites 30 min per site on weekday/weekend × morning/afternoon/evening

4 Street Intercept Interviews
Motivations, barriers and suggestions
- Deep dives the 'why' behind behaviours
- Surfaces contextual barriers and opportunities for Phase 2

n = 30, Recruited at observation sites

INTEGRATION & TRIANGULATION OF FINDINGS



Spatial Analysis + Behavioural Insights + Observations + Interviews
- Cross validates findings across methods
- Builds a holistic understanding of enablers and barriers in Phase 1

FROM INSIGHTS TO ACTION

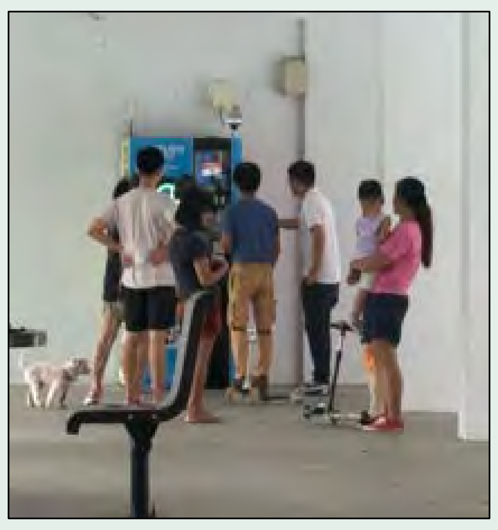
1. Policy Implications & Opportunities
Findings to Guide Policy Opportunities for BCRS Phase 2 Optimisation

2. ReturnO.S.™
AI powered app to support Participation and Planning

A mixed-methods framework integrates 4 methods to examine the socio-spatial factors influencing BCRS participation.

1) Geographic Information Systems (GIS),
2) Online surveys,
3) On-site observations, and
4) Street intercept interviews

Findings are triangulated to develop evidence-based planning recommendations for *ReturnO.S.™* and future BCRS optimisation (Phase 2).

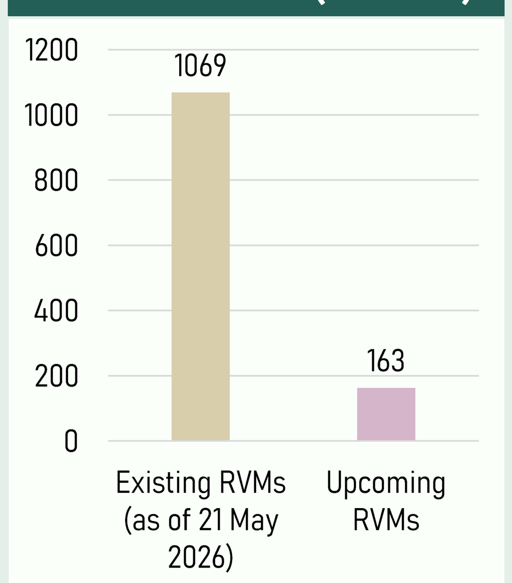


Taken during Field Observations at Block 9 Toh Yi Drive

Taken during Field Observations at The Rail Mall Cold Storage

4 RQ 1: HOW ACCESSIBILE IS THE CURRENT RVM NETWORK?

STATUS OF RVMs ISLANDWIDE (n=1232)

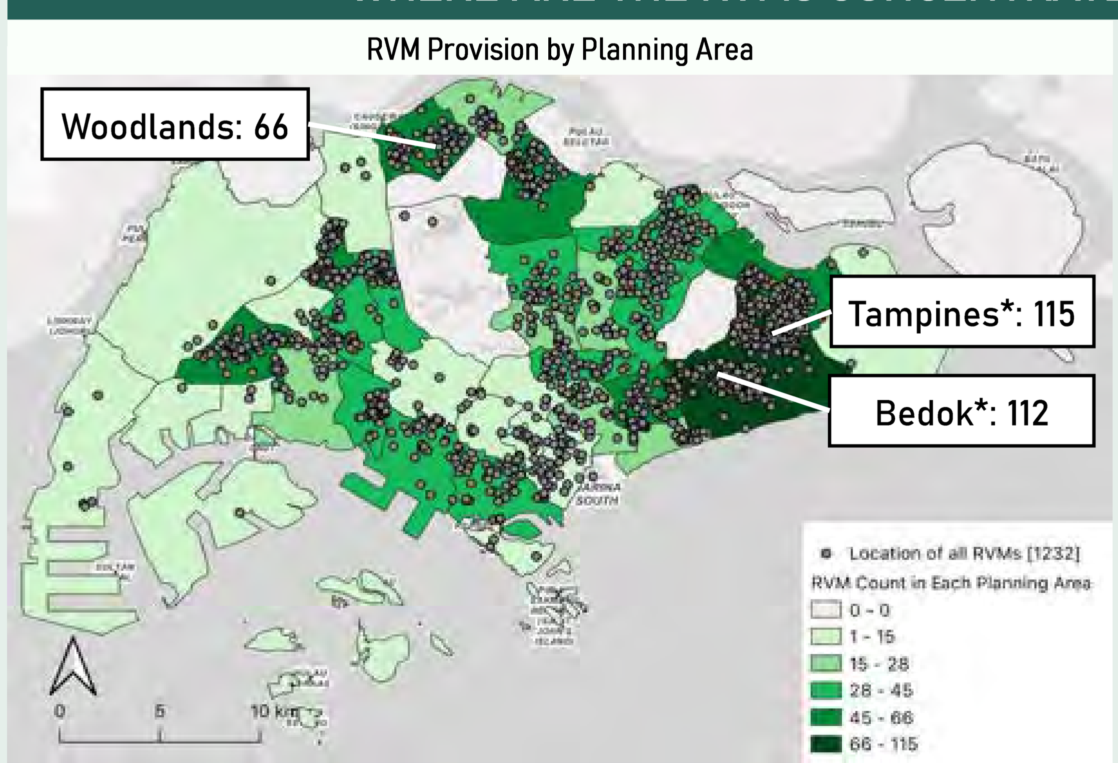


Source: Authors' own

Note: Analysis reflects the early implementation phase of the BCRS and is based on RVM locations available at the time of analysis (as of 21 May 2026)

WHERE ARE THE RVMs CONCENTRATED?

RVM Provision by Planning Area



Source: Authors' own
**Our Study Observation Sites; Planning area averages provide an overview of spatial provision and do not reflect accessibility at the neighbourhood level.*

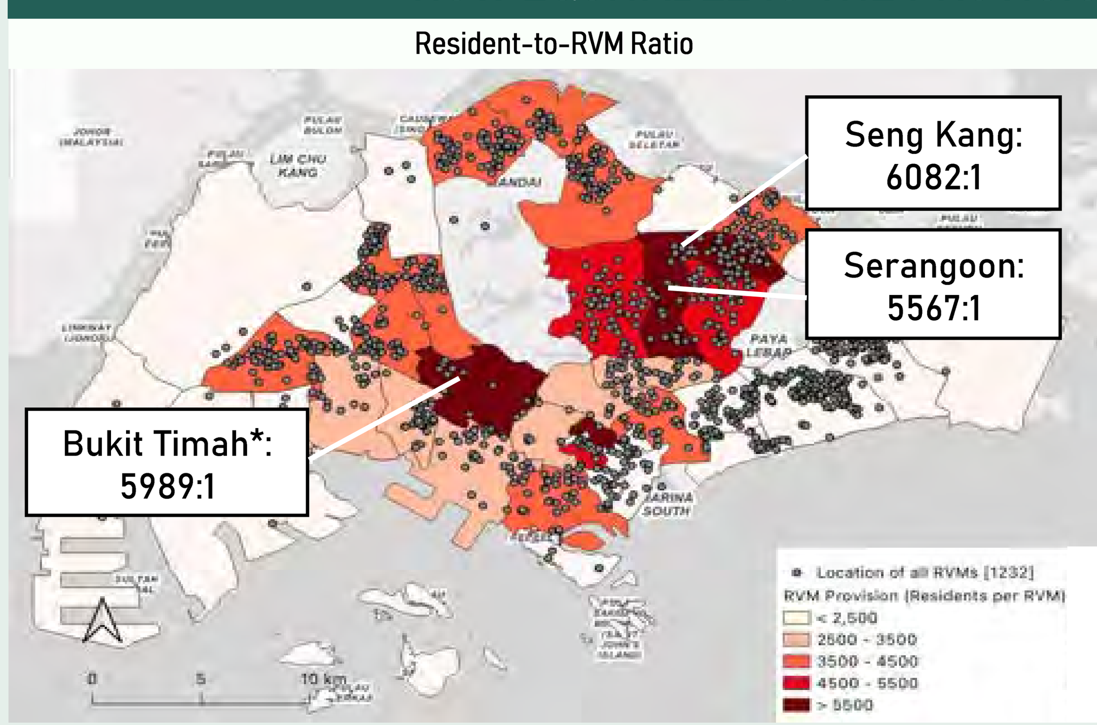
Planning Areas with highest number of RVMs:

RVMs are concentrated in large residential planning areas such as Tampines, Bedok and Woodlands. However, absolute RVM counts largely reflects the scale of deployment rather than the level of accessibility provided.

Population-adjusted measures, such as Resident-to-RVM Ratio, reveal disparities masked by absolute counts.

HOW EQUITABLE IS THE PROVISION?

Resident-to-RVM Ratio



Source: Authors' own
**Our Study Observation Sites; Non-residential planning areas (e.g., Tuas, Pioneer, Western Islands, Museum) were excluded from comparison as their specialised land uses and low residential populations make residents-per-RVM an unsuitable indicator.*

Planning Areas with highest residents to RVM Ratio (Normalised by Population):

Bukit Timah, Serangoon and Sengkang have comparatively more residents served by each RVM.

Planning Areas with high Resident-to-RVM Ratios may experience lower accessibility and greater competition for facilities.

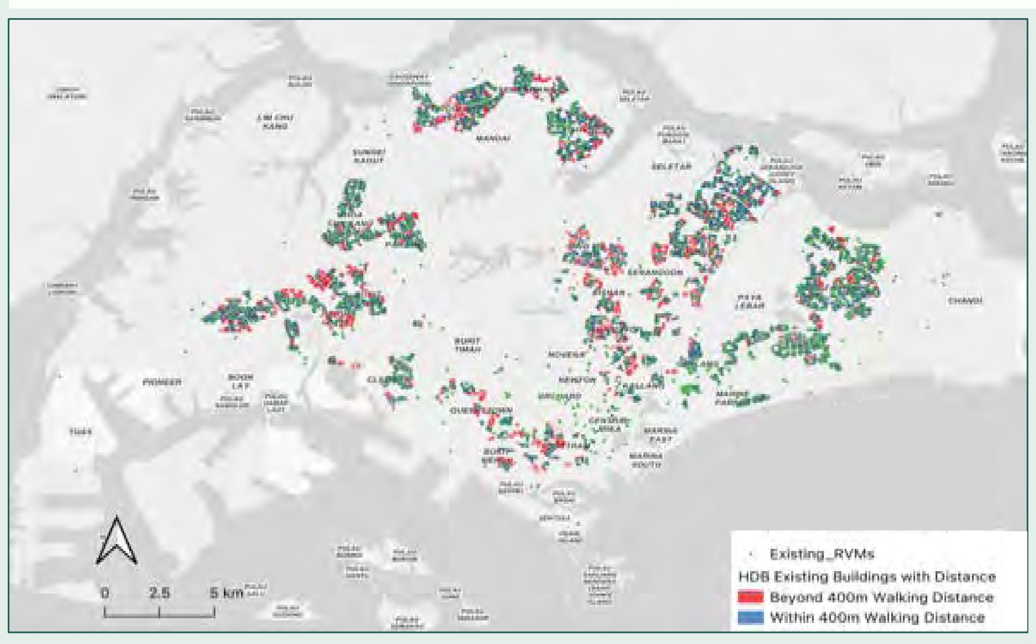
1,232 RVMs deployed Islandwide in Phase 1

Extensive Coverage across the island. However, accessibility varies considerably between neighbourhoods.

Further analysis beyond RVM counts is required.

CAN RESIDENTS WALK TO AN RVM?

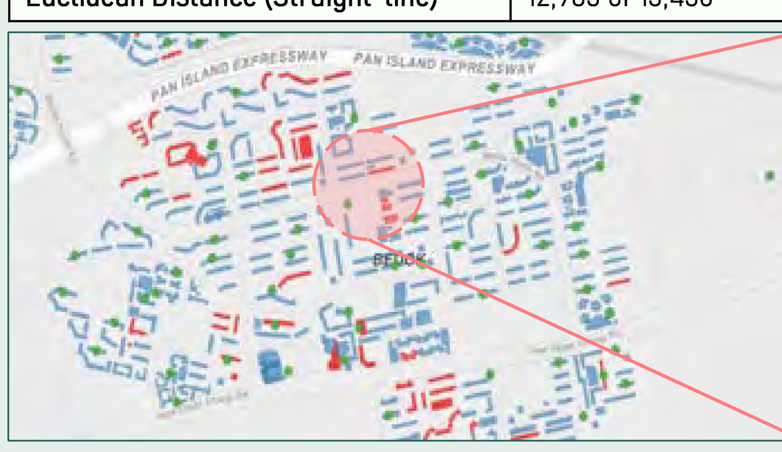
Straight-line (Euclidean) Distance Overestimates Accessibility Compared to Walking Distance



Source: Authors' own.
Data sources: data.gov.sg (HDB Buildings), OpenStreetMap (Pedestrian Network)

Walking accessibility is substantially lower than straight-line estimates.

Measure	HDB Blocks within 400m	Percentage
Walking Distance (Network)	9,002 of 13,436	67.0%
Euclidean Distance (Straight-line)	12,983 of 13,436	96.6%



Note 1: Accessibility assessed from HDB Block Centroids to nearest existing RVM along pedestrian network
Note 2: 400m Walking Distance is approximately a 5-minutes walk

KEY FINDINGS

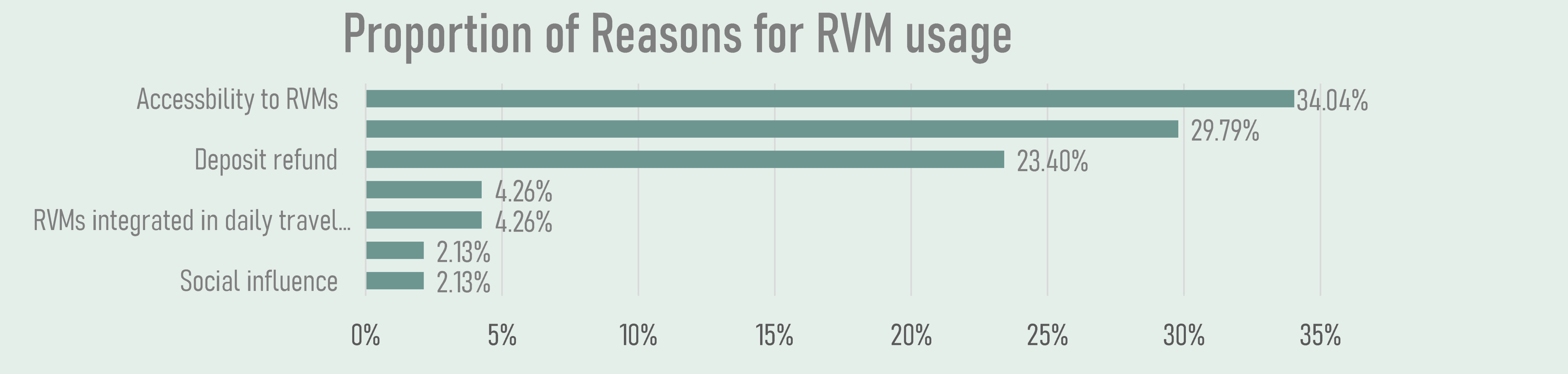
1 **Extensive RVM Coverage islandwide but Accessibility remains uneven.** This affects distribution of RVMs spatially within each neighbourhood.

2 **Metrics adjusted to take into account population and density reveal disparities.** Residents per RVM highlights differences in RVM provision across planning areas.

3 **Walking Distance provides a more realistic measure of Accessibility.** Future RVM planning should prioritise Walking Network over Radial Distance.

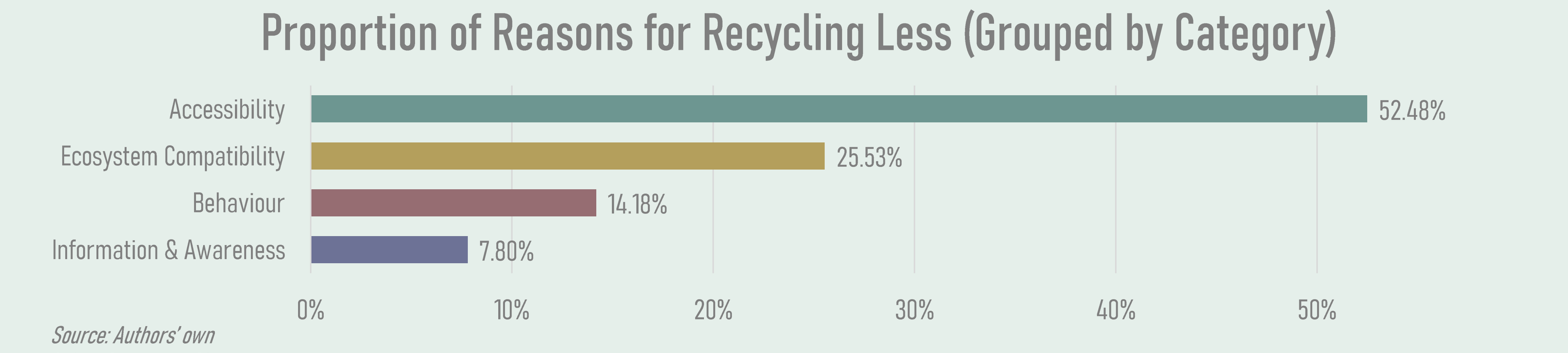
5 RQ 2: HOW DO SOCIO-SPATIAL FACTORS INFLUENCE RVM USAGE?

ACCESSIBILITY



Source: Authors' own
Online Survey, n = 47

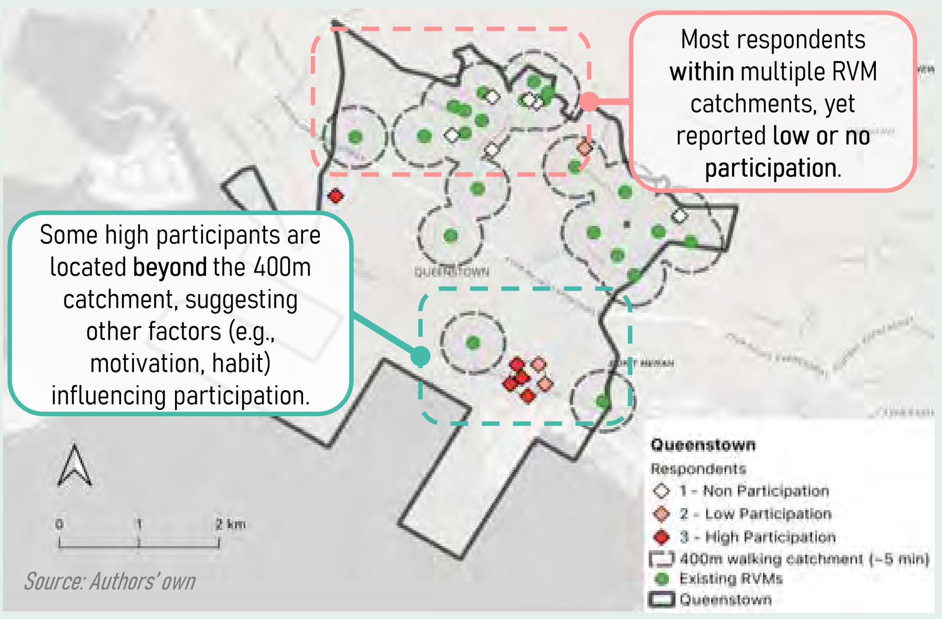
Accessibility was the strongest reported motivator for RVM usage.



Source: Authors' own
Online Survey, n = 31
Participants may choose more than 1 option for this survey.

Lack of Accessibility was the highest reported barrier to RVM Usage.

CASE STUDY 1: QUEENSTOWN

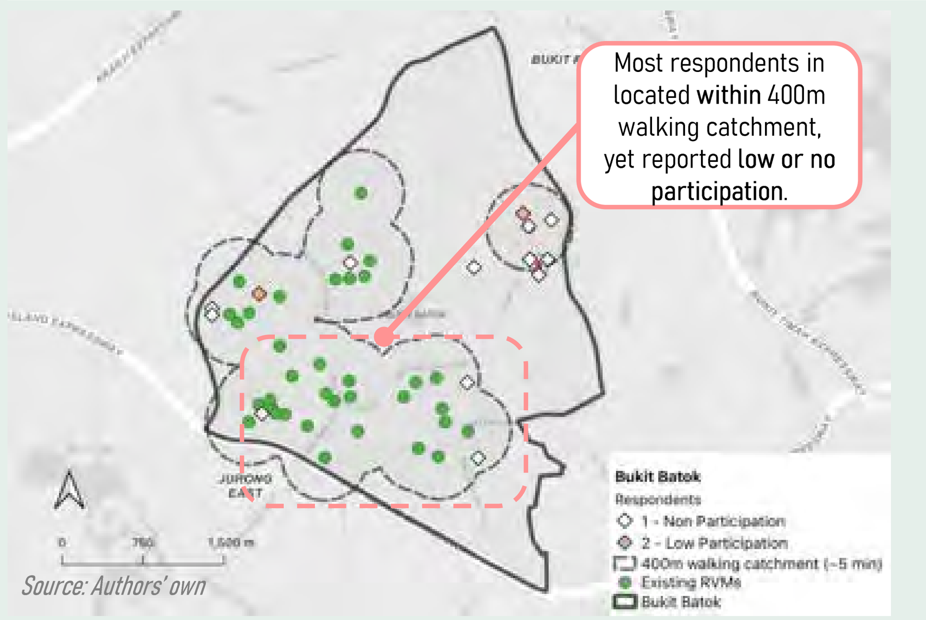


Source: Authors' own

- Representative case study
- Respondents from all participation groups
- Largest number of high-participation respondents (n=5)

64% (9/14) within 400m catchment reported Low or No BCRS participation

CASE STUDY 2: BUKIT BATOK

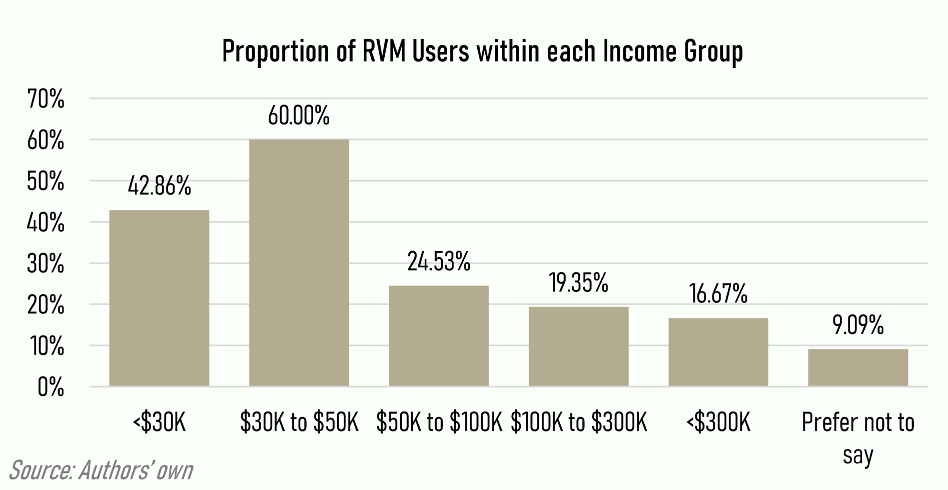


Source: Authors' own

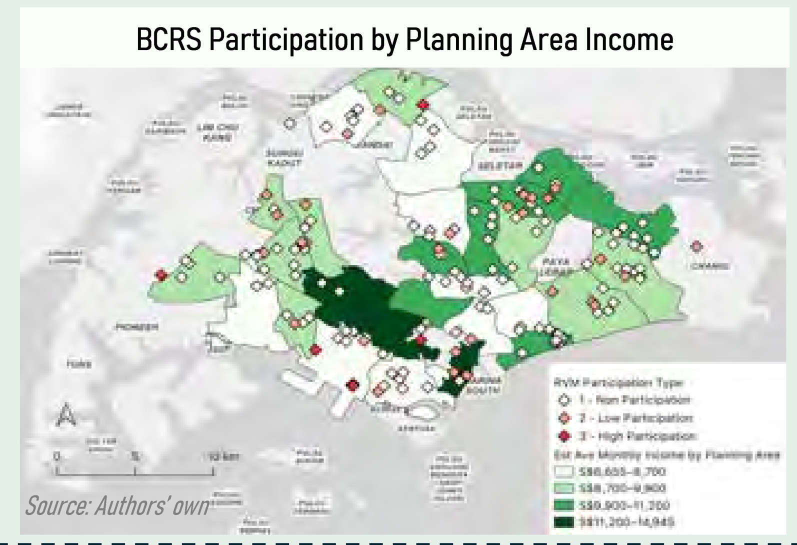
- Contrasting case study
- No High-Participation respondents
- Longer Mean Walking Distance to nearest RVM than Queenstown (470m vs 362m)

100% (14/14) within 400m catchment reported Low or No BCRS participation

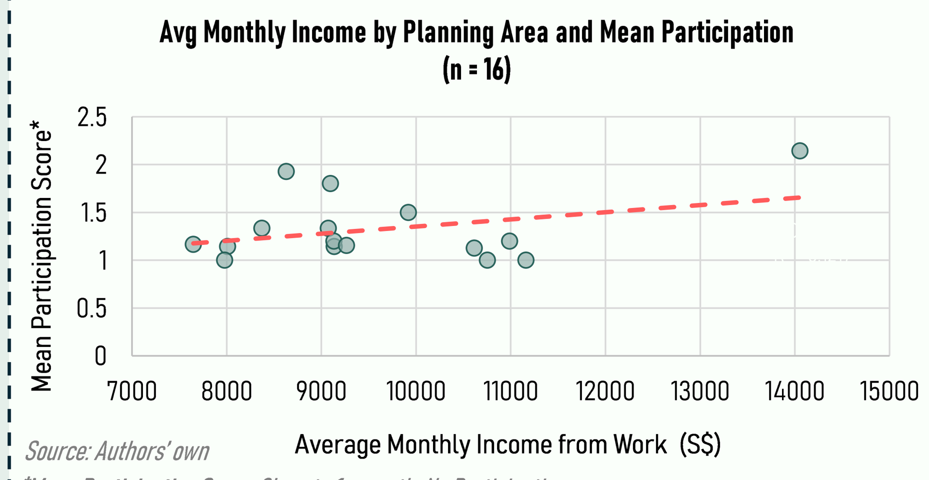
INCOME



Source: Authors' own
Online Survey, n = 171, RVM Users = 47



Source: Authors' own



Source: Authors' own
*Mean Participation Score: Close to 1 = mostly No Participation;
Close to 2 = Generally Low Participation; Close to 3 = Generally High Participation

KEY FINDINGS

1. Accessibility is **perceived to be important.** However, it is **not yet established** as the strong determinant of BCRS participation.

2. **Income shows a weak relationship with participation.** Participation occurred across all income groups and planning areas, suggesting that socio-economic status is not a strong predictor of participation.

6 RQ 3: HOW TO OPTIMISE BCRS PHASE 2?

A POLICY OPPORTUNITIES

CIRCULAR SYSTEM FRAMEWORK

Feature **matches users to suitable RVMs** based on real-time capacity, route convenience, container load, preferred proximity and premise-level wayfinding.

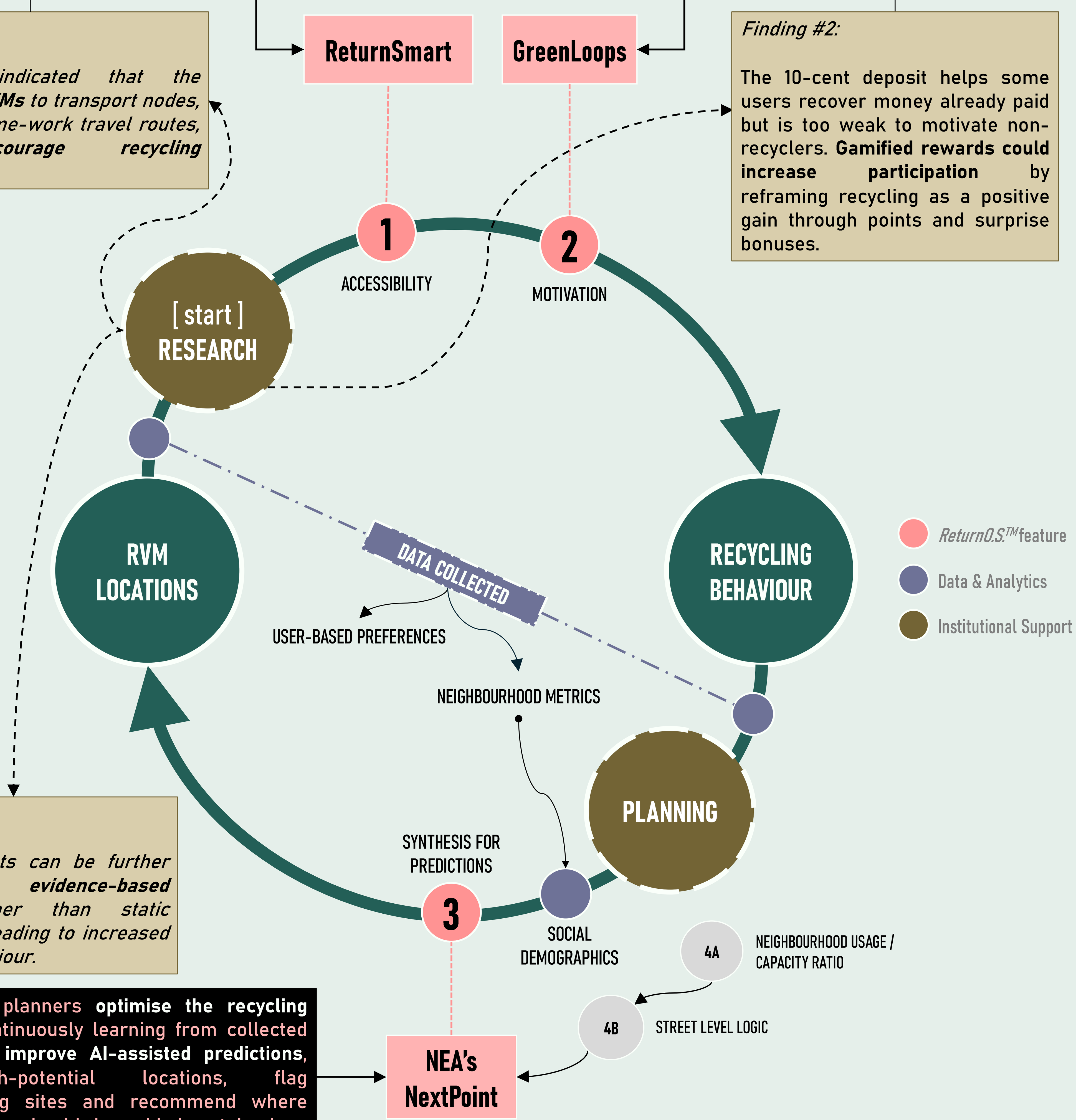
Feature lets users earn points from pre-sorting recyclable containers, unlock them through RVM returns and redeem Green Points to **offset Utility Bills**.

Finding #1:

*Participants indicated that the **proximity of RVMs** to transport nodes, along their home-work travel routes, would **encourage recycling participation**.*

Finding #2:

The 10-cent deposit helps some users recover money already paid but is too weak to motivate non-recyclers. **Gamified rewards could increase participation** by reframing recycling as a positive gain through points and surprise bonuses.



Finding #3:

*RVM placements can be further optimised by **evidence-based planning** rather than static assumptions, leading to increased recycling behaviour.*

Feature helps planners **optimise the recycling network** by continuously learning from collected usage data to **improve AI-assisted predictions**, identify high-potential locations, flag underperforming sites and recommend where recycling points should be added, retained or relocated.

The *Circular System Framework* positions RVM Location and Recycling Behaviour as a socio-spatial feedback loop. Quantitative Analysis identifies how accessibility, urban routines, demographics and motivation influence RVM usage, while Qualitative Interviews explain and validate these relationships. The findings highlight opportunities to address user barriers and optimise RVM planning through an evidence-based and adaptive approach..

Building on this, the research team developed *ReturnO.S.™*, an AI-enabled application supporting the BCRS ecosystem. *ReturnSmart* and *GreenLoop* guides users to RVMs and encourages participation by strengthening accessibility and motivations.

NEA's NextPoint feature uses socio-spatial metrics to optimise RVM deployment through data-driven recommendations. By integrating behavioural insights with real-time analytics, the system enables continuous optimisation of BCRS and container recycling rates in Singapore.

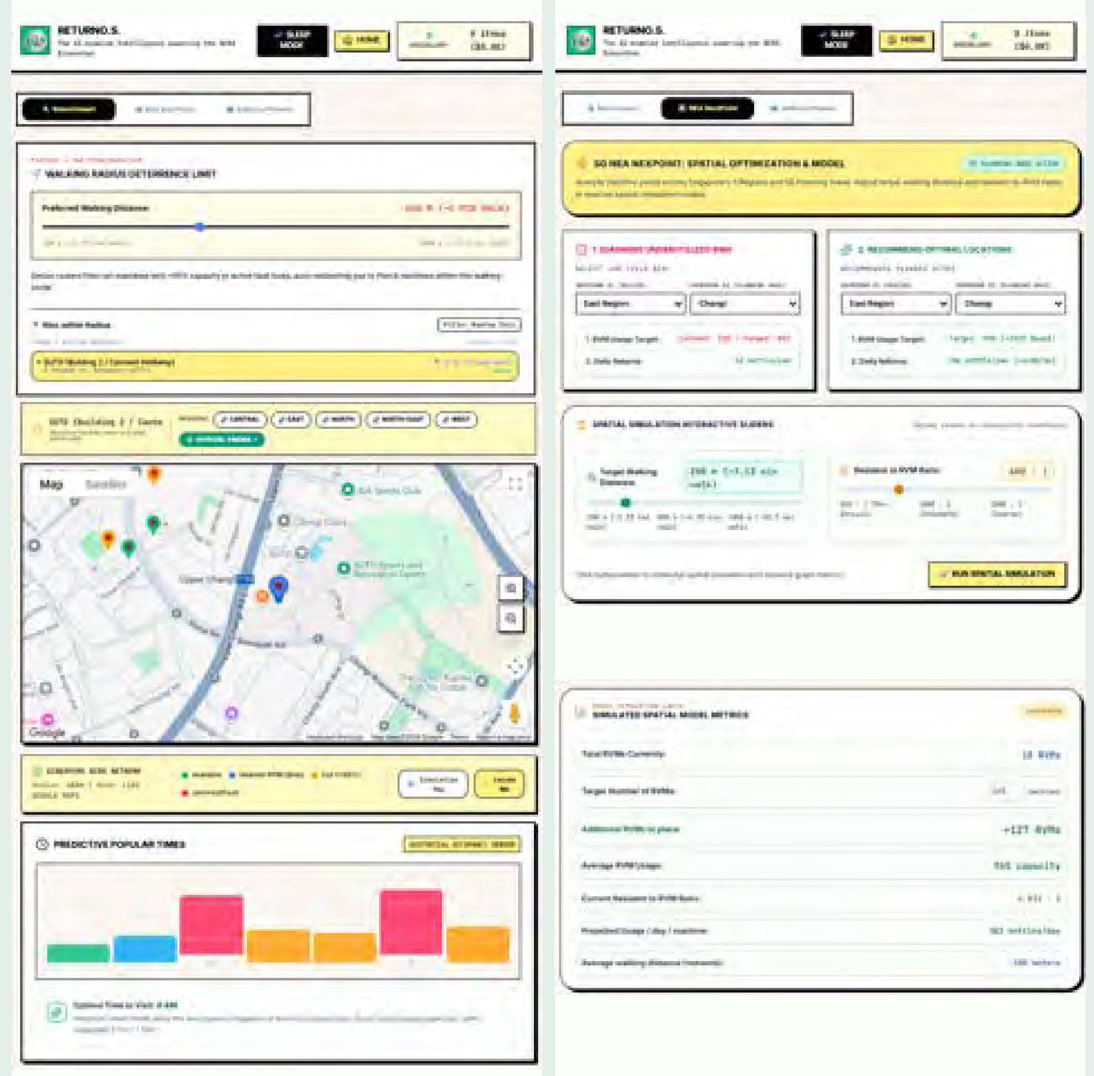
B ReturnO.S.TM

EXPERIENCE RETURNING

Best experienced on a digital device.
Scan the QR code or access the link below:

URL: *https://returnos-eight.vercel.app/*

USER-FACING *ReturnSmart*	PLANNING-FACING *NEA's NextPoint*



FILTERS

1. **Capacity**: Excludes RVMs that are at or above 95% capacity.
2. **RVM Typology**: Matches available RVMs to time of visit and number of containers to recycle.
3. **Route**: Identifies RVMs located along user's transit route.
4. **Distance**: Identifies suitable RVMs within user's preferred distance.

PARAMETERS

1. **Neighbourhood**: Selects Area targeted for intervention.
2. **Target Usage**: Sets desired increase in RVM usage (per machine per day).
3. **Walking Distance**: Sets the target distance, based on walking network.
4. **Capacity Ratio**: Sets Resident-to-RVM Ratio, from 100:1 to 1,000:1.

8 CONCLUSION

The findings suggest that integrating recycling infrastructure into everyday travel routines may encourage greater BCRS participation.

However, accessibility alone does not necessarily translate into higher participation as recycling behaviour is influenced by other socio-spatial factors. These findings provide the foundation for the *Circular System Framework* and *ReturnO.S.™* for future RVM deployment and user engagement.

Future Research:
Moving beyond RVM quantity, the next phase of research can focus on Accessibility as a measure of success, through walking networks connecting key destinations to RVMs.

Longitudinal Surveys should also be adopted into the methodology to track individual recycling behaviour over time in response to the evolving socio-spatial conditions.

Understanding Urban Environmental Experience Through Audio–Visual Prediction and Perceptual Validation

The Case of Pasir Ris, Singapore

By: Komila Mirzaeva · MUSPP · 1010711
Supervisor: Li Bayi · Co-supervisor: Sarah Chan

how the neighbourhood sounds and looks? interactive map

We evaluate cities with our eyes

Urban design decisions run on visual evidence like renders, street-views and photo audits. Sound is assumed to follow. It doesn't.

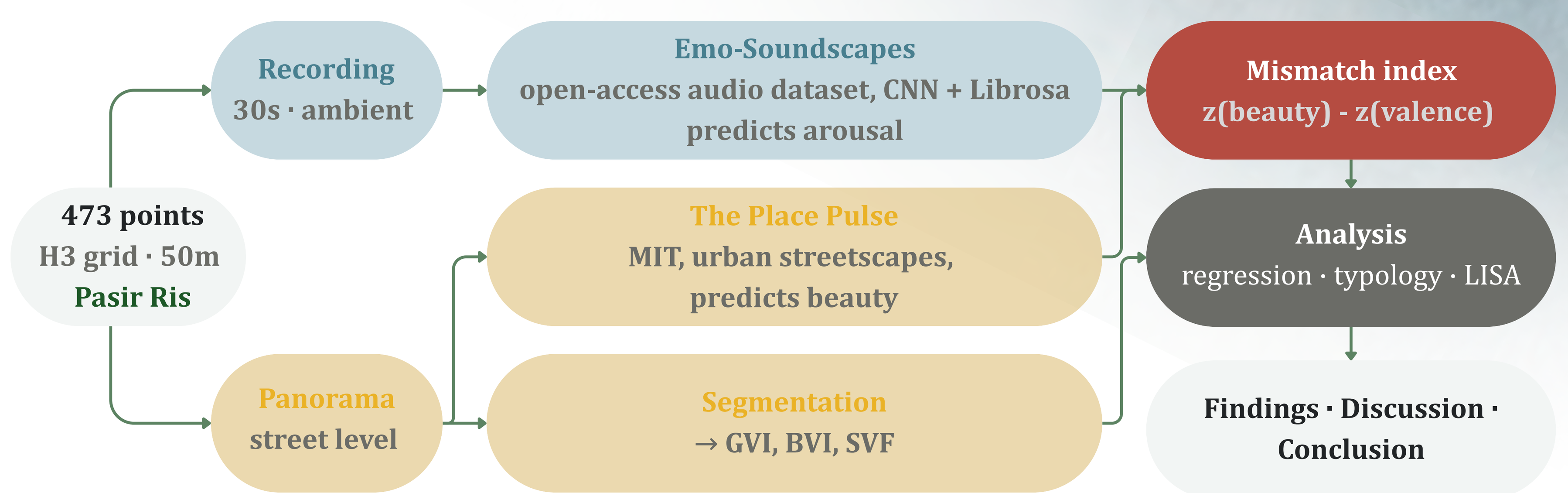
A place can look like a park and sound like a highway

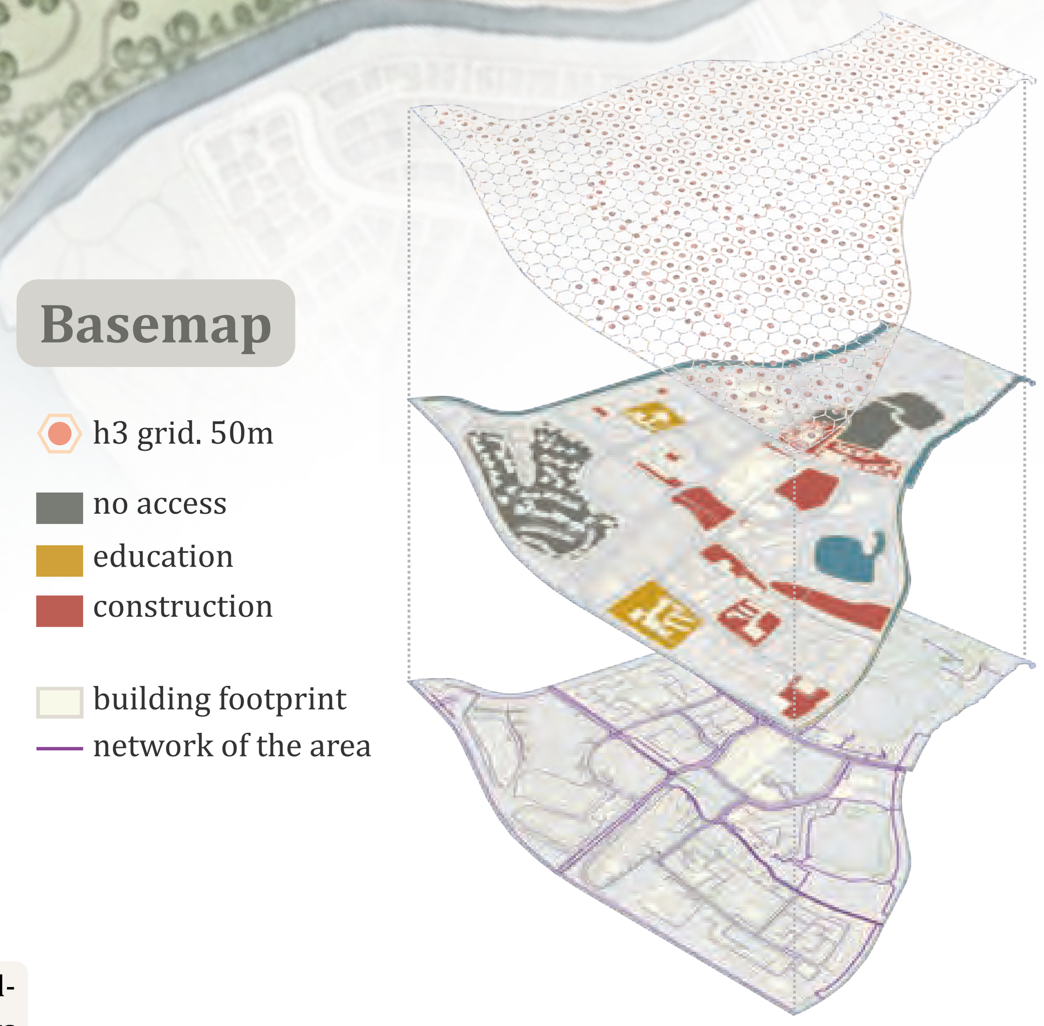
Visual review has a blind spot in that it is purely visual. A place can pass every review and still fail the ear.

This thesis makes that blind spot measurable

Framework & Method

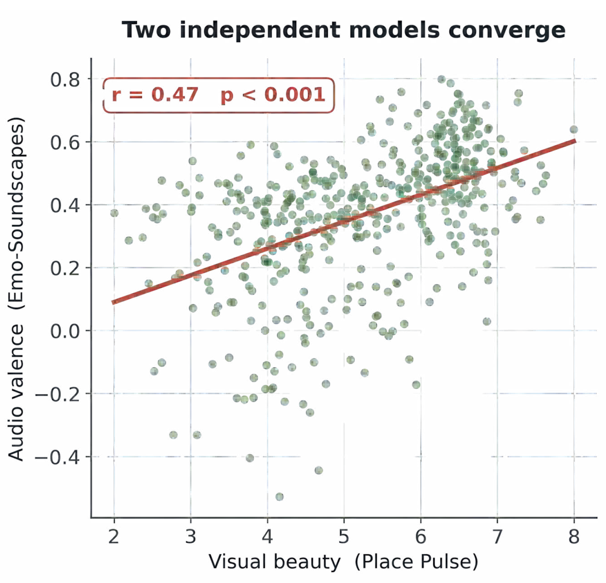
RQ1 · Prediction: How do visual and acoustic qualities vary across Pasir Ris?
RQ2 · Coherence: Where do sight and sound diverge, and into what types?
RQ3 · Built form: What predicts coherence, divergence, and its direction?

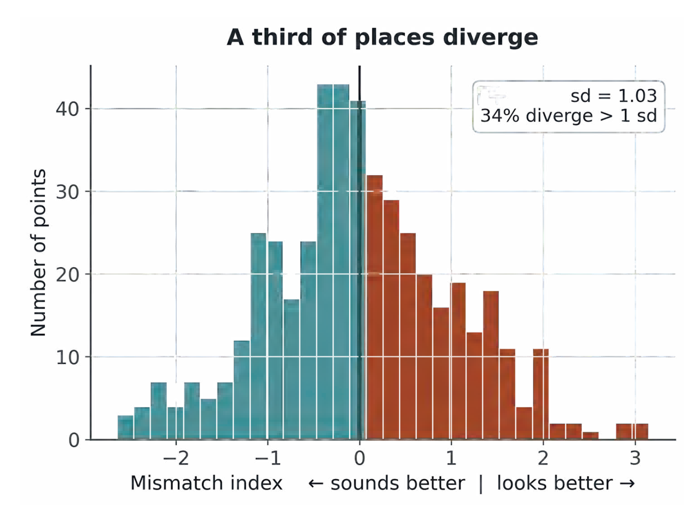


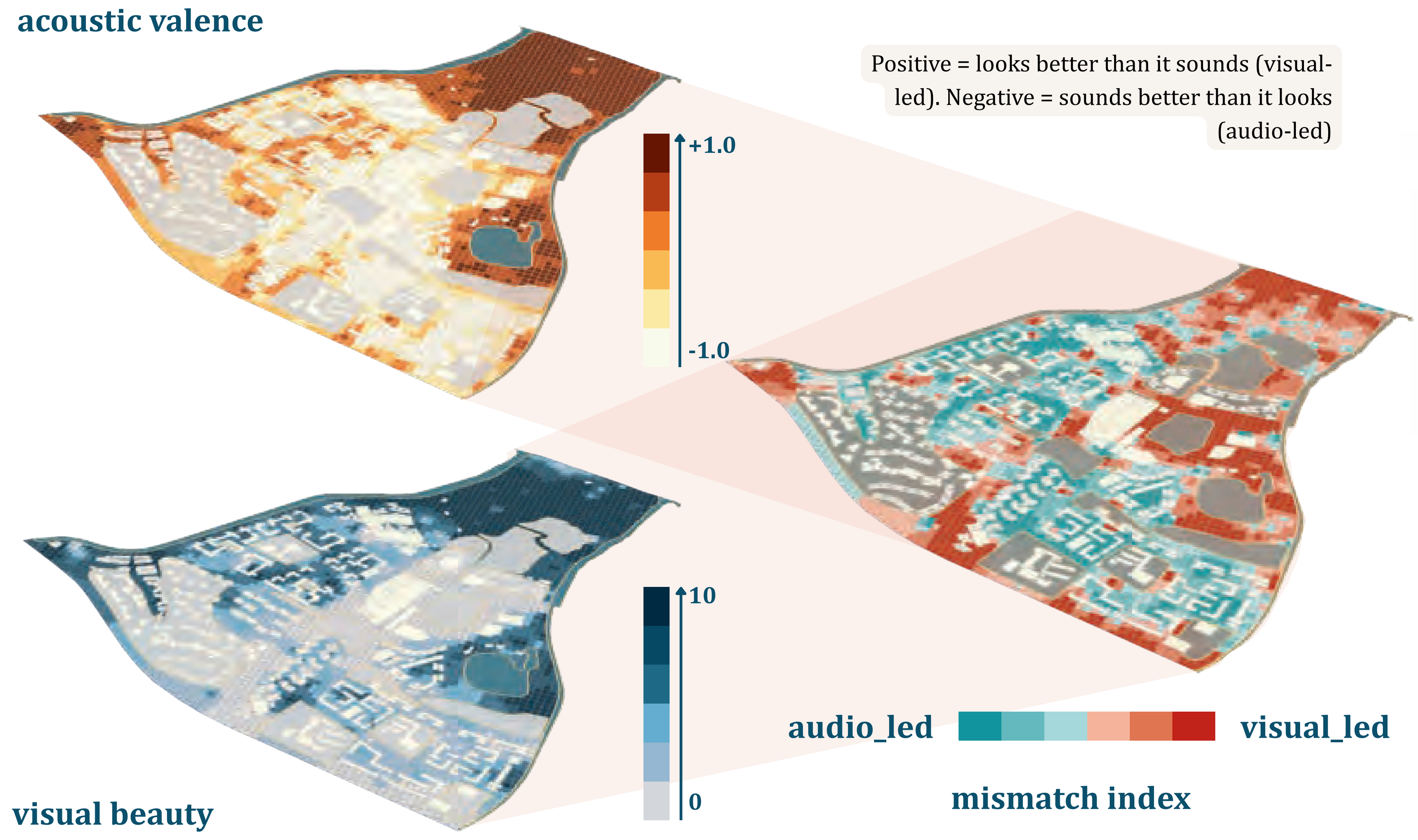


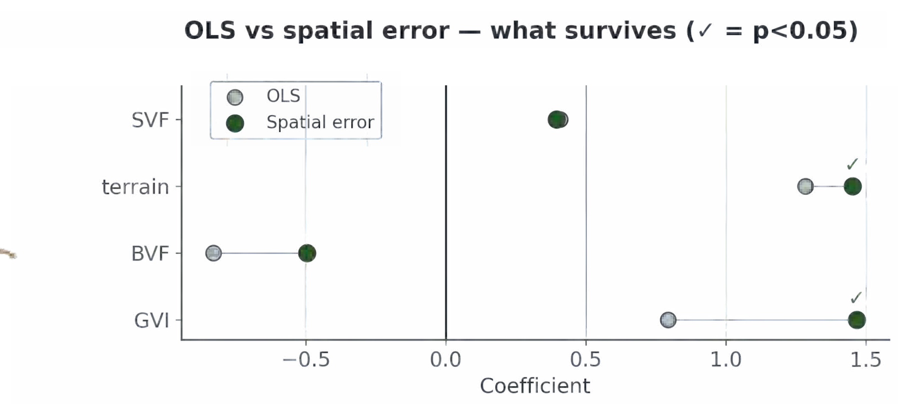
The Mismatch

34% of points diverge by more than one standard deviation between how they look and how they sound. Sensory mismatch is systematic, it is not noise. Two independent models converge at **r = 0.47.** Strong enough to trust both channels, but loose enough to leave real mismatch to explain.





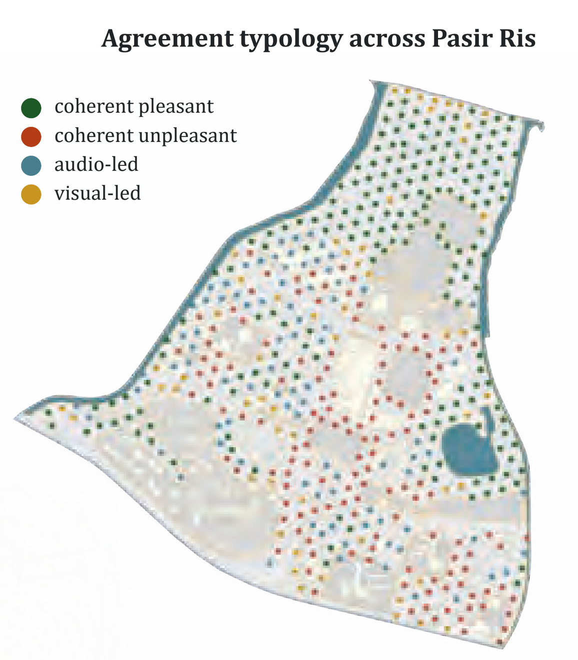


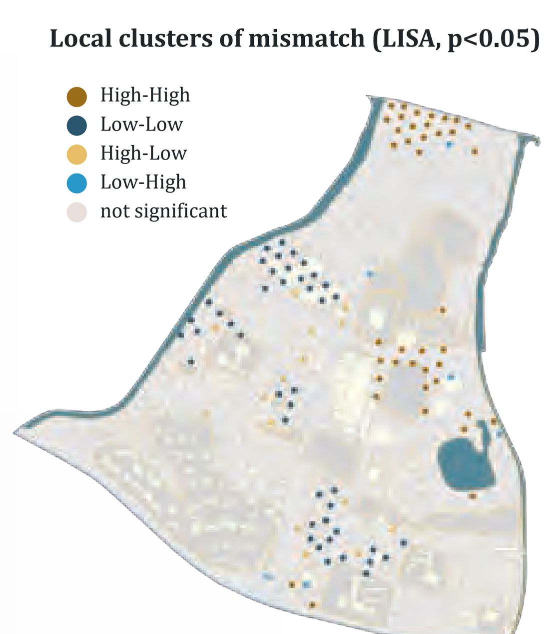


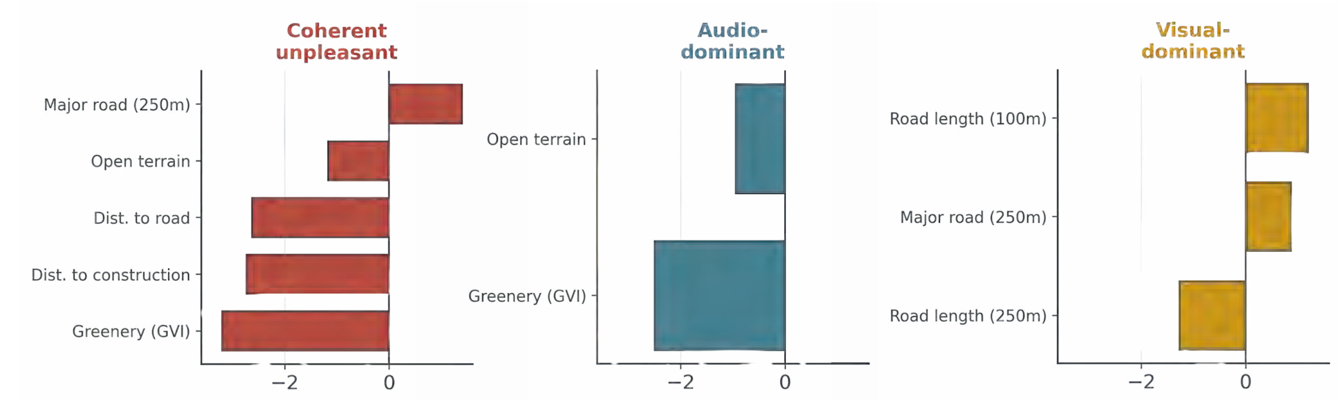
The mismatch index isn't randomly scattered, Global Moran's I = 0.21 (p = 0.001) confirms real spatial clustering, so a spatial error model was used instead of standard regression. Of seven candidate predictors, only two hold up: greenery (GVI) and open terrain significantly predict which way a site tips (p<0.05), and both effects strengthen once spatial autocorrelation is corrected. Road proximity, construction distance, and water distance show no effect at all.

Four ways senses can (dis)agree

Coherent pleasant dominates the north: park and waterfront points where sight and sound agree. Coherent unpleasant concentrates south-central, near roads and construction. Audio-led and visual-led points sit at the boundaries between these zones. Local clusters of mismatch (LISA, p<0.05) · Global Moran's I = 0.21 (p = 0.001). High-High marks a real visual-led zone; Low-Low marks a real audio-led zone.

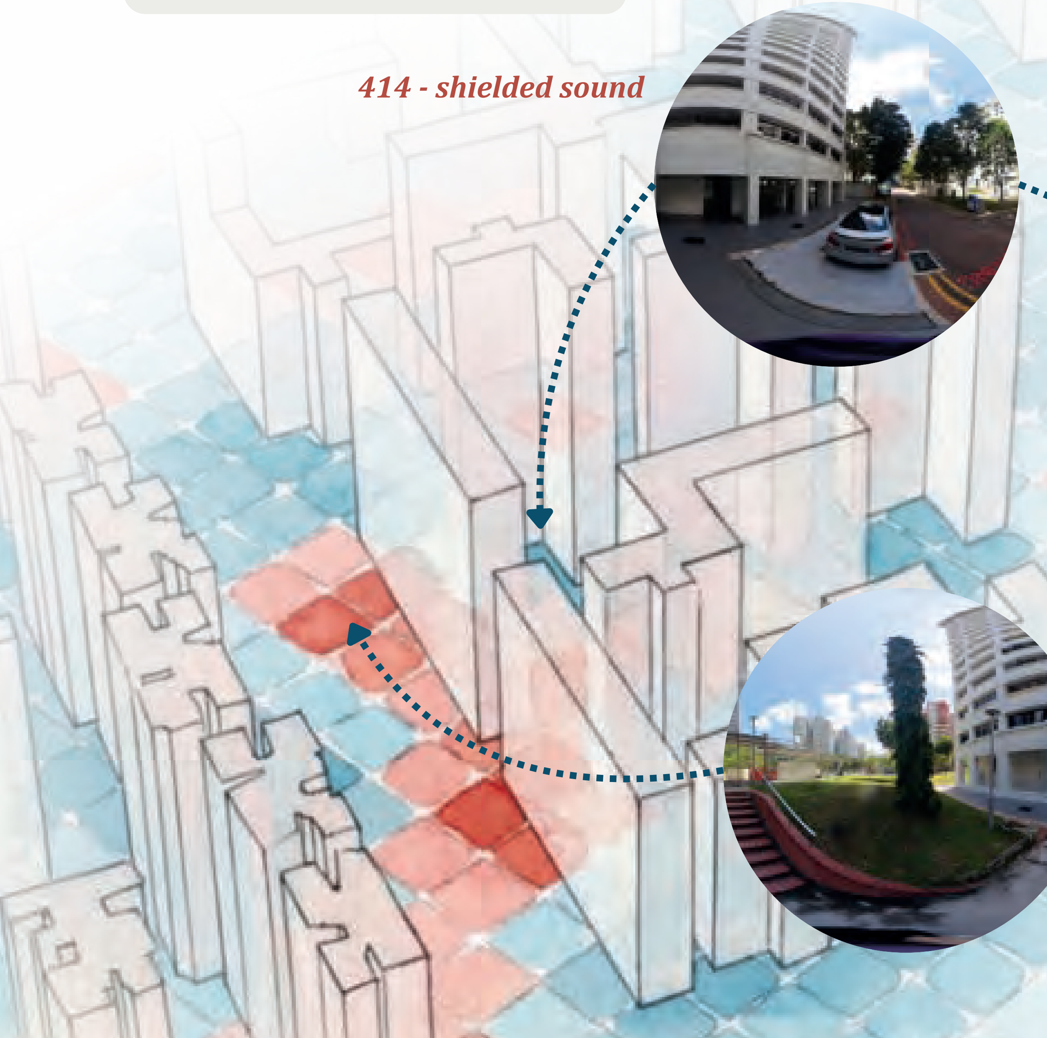


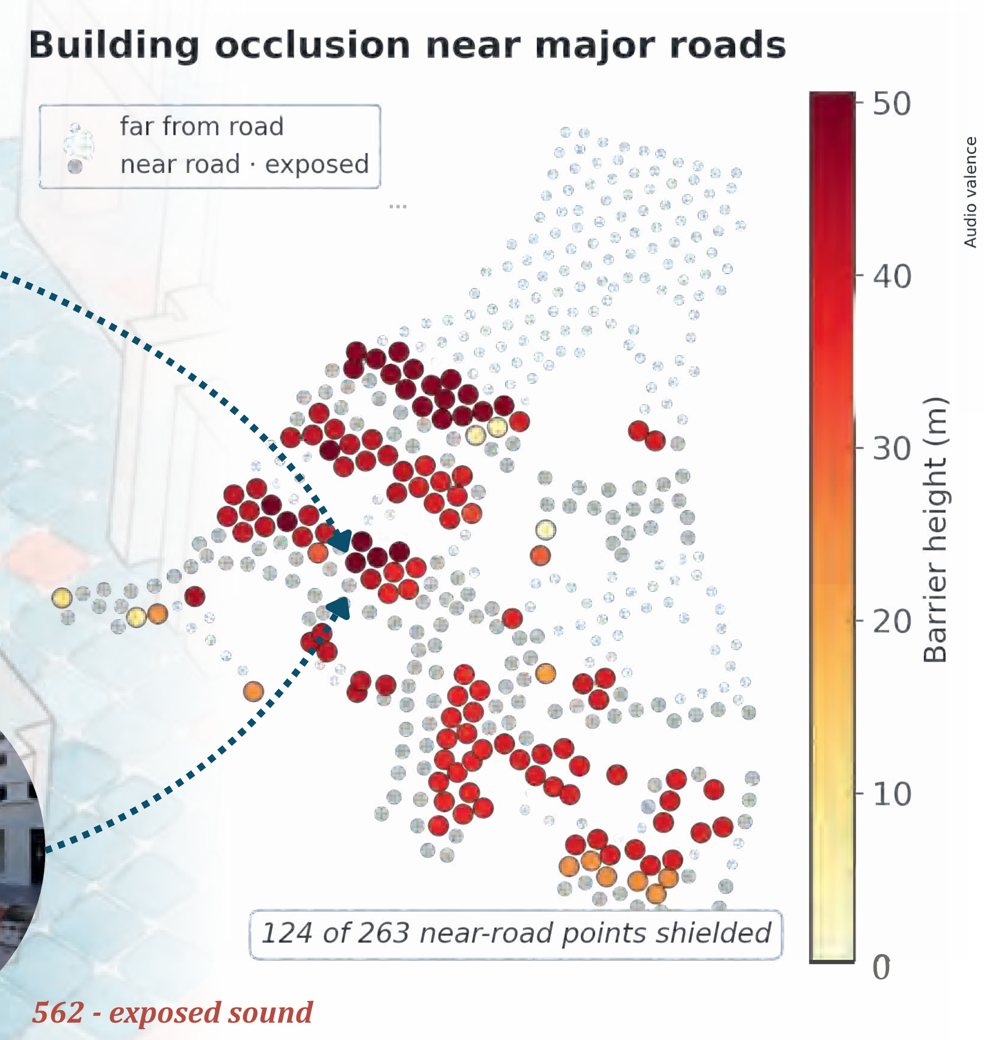


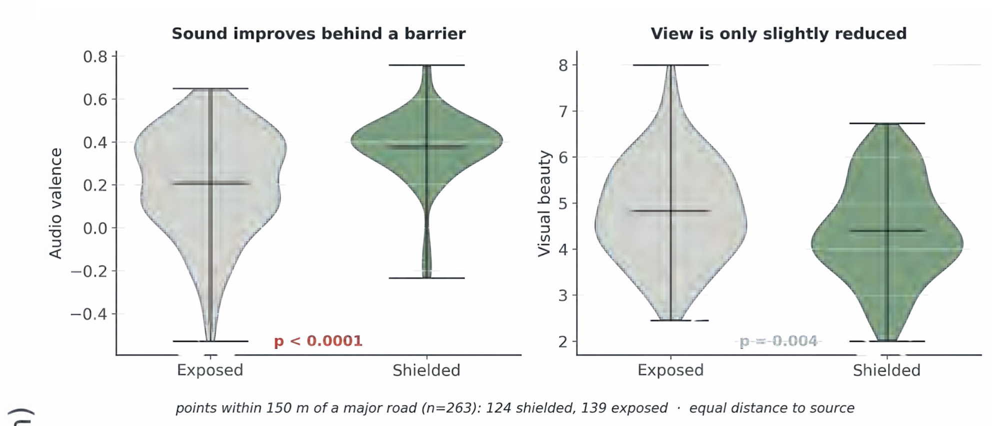


The same pattern that separates categories on the left forms real spatial clusters on the right

The Barrier Effect







A building barrier is the only difference between two otherwise identical roadside points. 124 sit shielded; 139 sit exposed. Point 414 (shielded): sound +0.72, quiet despite the traffic. Point 562 (exposed): sound +0.24, worse sound despite looking nicer (beauty 6.2 vs. 4.3). Shielded sites gain sound (+0.40 vs. +0.22, p<0.0001) but lose little on looks (4.31 vs. 4.74, p=0.004). The barrier doesn't balance sight and sound, it swaps which one wins.

What Urban Planning Gains

The Tool

A diagnostic framework. Runs on panoramas and recordings alone, producing a mismatch map of any existing district. Flags the visual-led "traps" that visual audits miss

The Principle

Massing as acoustic infrastructure. Position buildings to shield the spaces behind them from road noise, the way we already design for wind and sun. Regulate placement

The Caution

Sound can't be read from sight. A green buffer or a pleasant render isn't evidence of acoustic quality, vegetation alone doesn't shield. Coherence must be measured, not assumed

FROM TOOLS TO PRACTICE

Behaviour Gap and Organisational Dynamics in AI Tools Adoption among Urban Planning Practitioners and Researchers in Singapore

Authors:
Loh Yan Yi Stephanie_1010698
Pham Nguyen Trang Dai (Caroline)_1010714
Yakdehige Inodee Rusanja Fernando_1010710
Under the supervision of Dr. Thijs Willems

RESEARCH BACKGROUND

Today — Social technical governance
- Gen AI
- Digital twins
- Ethical boundaries
- Professional identity challenges

2010 — Critical turn (Smart city)
- Challenge techno-solutionism
- AI as political instrument
- Focus: What AI should do

2000 — Technological Optimism
- GIS
- Decision-support
- Rational computational lens

THE STRUCTURAL PARADOX

Technological Pressure
- Market competition
- Operational efficiency
- "Adopt AI now!"

Adoption is NOT individual choice

Professionals caught in the middle

→ It's organizational negotiation (Orlikowski, 2000)

Academic/ Governance Caution
- Socio-technical risks
- Ethical complexity
- "Preserve human agency"

THE THEORETICAL BLIND SPOTS

Both LENS are valuable but MISSING the MECHANISM

Individuals within Organizational contexts

Research purpose

The rise of AI
- Digital Twins
- NLP, LLMs
- machine learning
- generative AI
- ...

what AI can do?

Technological lens

Assumes superior technology → natural adoption

Hidden emotional cost

Urban Planning Professionals

Structural friction
Verification labour

Organizations

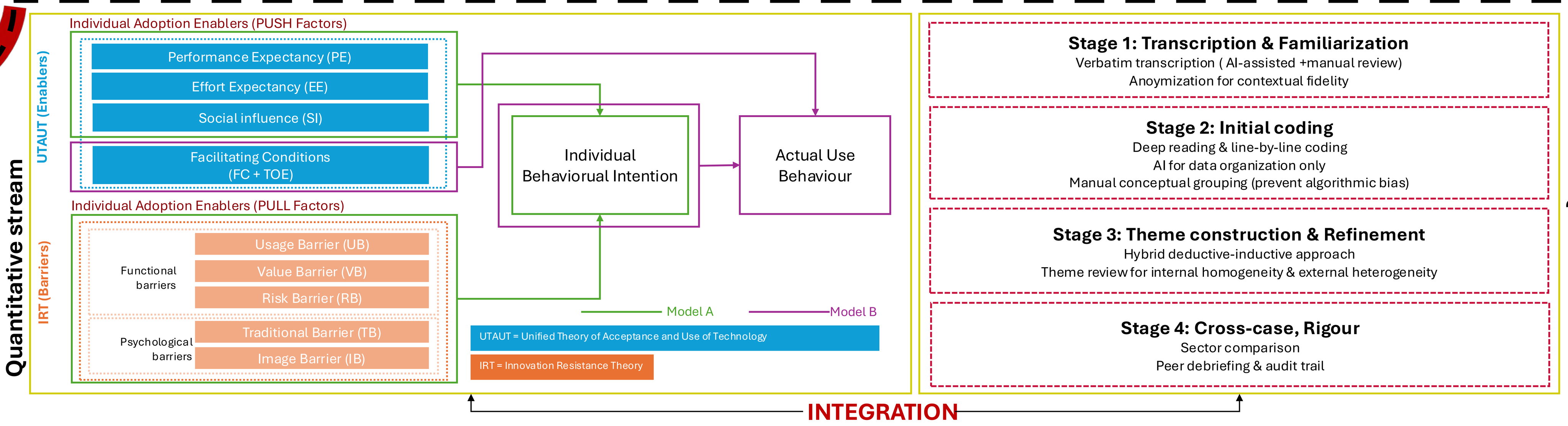
TAM - Davis, 1989,
UTAUT - Venkatesh et al., 2003,
IRT - Ram & Sheth, 1989

why individuals do or do not want to use it ?

Psychological lens

Focuses on perceived usefulness, effort expectancy, trust

METHODOLOGY



Semi-structured interviews
- **5** urban planners from 3 different government agencies
- **7** academics/ researchers
- **5** planners/ technical staff from private consultancies

FINDINGS

Forming Intention: Individual Enablers & Barriers

Construct	B	p	Result
PE	0.435	.034	Significant
EE	0.193	.330	ns
SI	0.240	.193	ns
UB	−0.054	.769	ns
VB	−0.023	.883	ns
RB	0.093	.558	ns
TB	−0.332	.063	Marginal
IB	0.044	.768	ns

70.8% of the variance in planners' intention to adopt AI tools was explained by the model ($R^2 = 0.708$), a statistically significant result even after accounting for the number of predictors relative to sample size (Adjusted $R^2 = 0.563$), $F(14, 28) = 4.858$, $p < 0.001$.

"AI really helps me with processing data… I have time to think and develop ideas." *Sector A, P05*

"I am old school… I still prefer I am the first-cut, then AI edits… I still want to have the self-discipline… I still retain the knowledge… I have the ground knowledge." *Sector C, P15*

Enablers

Performance Expectancy

Role-specific fit: Salience is highest when AI maps onto core tasks, GIS analysis, slope renderings, or visuals for supervisor buy-in.

Social Influence

Barriers

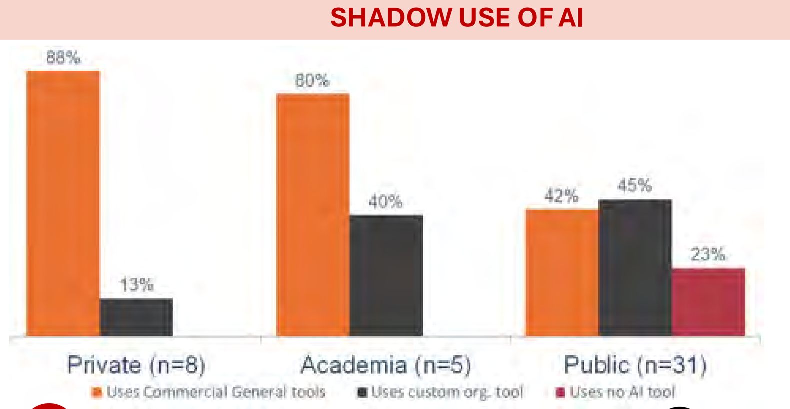
- Tradition & Image Barrier
- Security & confidentiality cincerns
- Verification effort
- Worflow and system incompatibility

Translation into Behaviour within Organisation Context

Construct	B	p	Result
Behavior Intension (Dependent Variable from Model A)	1.206	<0.001	Significant
Facilitating Conditions	-0.051	0.825	ns

While Facilitating Conditions showed no significant statistical effect on Actual Use (B = –0.051, p = 0.825), the qualitative interviews reveal why: when organisational infrastructure and guidance fall short, practitioners do not abandon AI, they route around the gap toward self-funded or unapproved tools.

SHADOW USE OF AI



This informal substitution constitutes "shadow AI," turning a null quantitative result into a visible behavioural pattern that the quantitative lens alone could not detect.

A Private Sector — Market pressure drives informal workarounds.

Copilot is promoted and training is available, but client confidentiality demands and competitive time pressure push staff toward self-funded external premium tools (with careful content filtering).

B Academic — Security rules collide with tool quality.

Cybersecurity policies and project contracts prohibit uploading raw or sensitive datasets, while officially supported tools are seen as weaker than commercial alternatives, producing earlier, more exploratory adoption but tempered by concern over academic originality and ownership.

C Public sector — Compliance dominates, adoption stays cautious.

The tightest constraints (secure-card laptops with no internet, strict data classification, lengthy procurement) confine AI to low-risk, sanctioned tasks; leadership explicitly signals that internal work must not go onto external AI tools, producing the slowest and most tool tiered translation of intention into practice.

Intention–use gap: BI mean 3.81 vs. AU mean 3.26 (–0.55 pts)

Navigating the Tension: Workarounds, Boundaries & Fatigue

Construct	B
Usage Barrier (UB)	2.94
Value Barrier (VB)	2.67
Risk Barrier (RB)	4.00
Traditional Barrier (TB)	2.86
Image Barrier (IB)	2.91

The Risk Barrier recorded the highest mean of all IRT constructs, suggesting that concerns over data privacy, hallucinated outputs, and legal liability, rather than usability.

"I will cut out the relevant paragraph… instead of 'dwelling units', I replace with 'apple'." - Secto… 5

"AI is supposed to be easy. But then I spend a lot of time checking! …especially when you are in the final part, it's so tiring. You could forget to check." - Sector B, P09

"For certain value judgments and decisions, especially when there's a moral or ethical dimension to it, we should still use our human judgments." - Sector C, P12

Faced with the gap between intention and constrained opportunity, participants engaged in continuous, pragmatic negotiation. Navigation not a one-off decision but an iterative process (boundary-setting, tool tiering and verification) that carried both practical and emotional costs.

Role-appropriate boundary-setting — Practitioners draw deliberate lines around tasks unsuitable for AI, hiring decisions, ethical judgements, and confidential data remain with human agency, protecting professional accountability.

Tool-tiering — A two-tier system: approved internal tools for organisational data, self-funded external tools (often anonymised) for ideation and personal productivity.

Iterative verification & emotional fatigue — A recurring cycle of prompting, checking, and re-prompting to catch errors, necessary for quality control, but one that erodes the efficiency gains that motivated adoption.

CONCLUSION

A persistent intention-behaviour gap

Urban planning professionals form positive intention, but Actual Use lags behind, shaped by individual, process and organisational forces.

Implications

To strengthen organisational conditions

- Clear, role-specific guidance on permissible and high-value AI use
- Ethical and security frameworks that reduce ambiguity, rather than restrict
- Better-integrated, domain-relevant AI capabilities (e.g. with GIS platforms)
- Acknowledgement of verification labour/ emotional cost

Limitations
- Limited sample size, confined to Singapore limits generalisability; sample skewed to Sector C (public sector).
- Intention and behaviour-use measured through self-report (subject to bias)
- Study captures a single moment, cannot track AI adoption patterns over time

Future Study
- Complementary methods – e.g. ethnographic observations
- Longitudinal study – track intention and use as AI tools/org. policies evolve
- Intervention studies – test practical recommendations

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LITERATURE REVIEW

THE SOCIO-TECHNICAL INTERACTION

Technology shapes work
- AI reduces time for tasks
- Enables new capabilities

Individuals shapes technology
- How people use/adapt/ circumvent AI
- Shapes governance & institutionalization

STRUCTURAL FRICTION (The Collision)

Individual aspirations ↔ Institutional frameworks

How urban planning professionals navigate their AI adoption through hidden cost and constraints? (NAVIGATION & HIDDEN COSTS)

THE PROPOSED FRAMEWORK (process lens)

1. INDIVIDUAL LEVEL (UTAUT + IRT)
   - Performance Expectancy → Intention
   - Barriers (Risk, Value, Tradition)
2. ORGANIZATIONAL FILTER (The Missing Piece)
   - Security-focused (not productivity-focused)
   - Legacy systems
   - Ambiguous guidelines
   - Leadership norms
3. NAVIGATION TENSION STRATEGIES
   - Boundary-setting
   - Informal workarounds
   - Tool tiering
   - Iterative verification
4. HIDDEN COSTS
   - Emotional fatigue
   - Cognitive overhead

RESEARCH QUESTIONS

RQ1. What individual enablers and barriers influence urban planning professionals intention to adopt AI tools?

RQ2. How do perceived organizational conditions influence urban planning professionals' actual AI adoption behavior?

RQ3. How do urban planning professionals practically navigate the tension between utilising self-directed AI tools and adhering to existing formal IT frameworks and policies?

Multi-sensory Evaluation of Urban Park Users' Stationary Behaviour

Chris-Duncan Allaix · Song Keat Tan · Inhwan Shin Supervised by: Dr. Sarah Chan MUSPP Master's Research Project 25/26 Singapore University of Technology and Design

LITERATURE REVIEW & RESEARCH GAPS

How can urban park usage be studied?

	Singapore	Overseas
Socio-spatial	Guo et al., 2024	Da Nang, Vietnam Do et al., 2019
Sensory	Thermal (Only) → Gap #1 Heng & Chow, 2019	Dhaka, Bangladesh → Gap #2 Visual · Aural Olfactory · Thermal Tabassum, 2025

KEY FINDING (Tabassum, 2025)

Sensory-rich "nodes" (e.g. tree-shaded seating, sports facilities) are associated with stationary use → Gap #3

RESEARCH GAPS

- #1 How might other senses influence park usage in Singapore?
- #2 Is the Dhaka finding universalisable to Singapore/ elsewhere?
- #3 What sensory type(s) could affect what stationary behaviour type(s)?

RESEARCH QUESTIONS

PRINCIPAL

How might **multi-sensory environmental variables** (visual, aural, olfactory, thermal) influence **urban park users' stationary behaviour** in Singapore?

SECONDARY

- SRQ 1 Describing urban parks' sensory environments
- SRQ 2 Understanding and clustering stationary behaviour
- SRQ 3 Non-sensory factors vs the sensory environment
- SRQ 4 Naturalistic vs anthropogenic sensory configurations

CONCEPTUAL FRAMEWORK

Sensory Environment SRQ 1
Visual* · Aural (Sound)* · Olfactory (Smell)* · Thermal
*Can be described as naturalistic vs anthropogenic

Non-Sensory Factors
Temporal · Spatial · Demographic

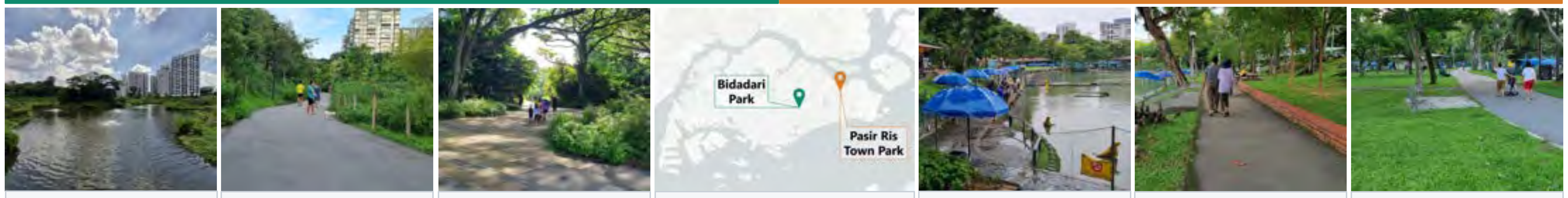
SRQ 3
SRQ 3
SRQ 4

Behaviour Characteristics
Activities · Facing Direction · Posture · Group Type/ Size

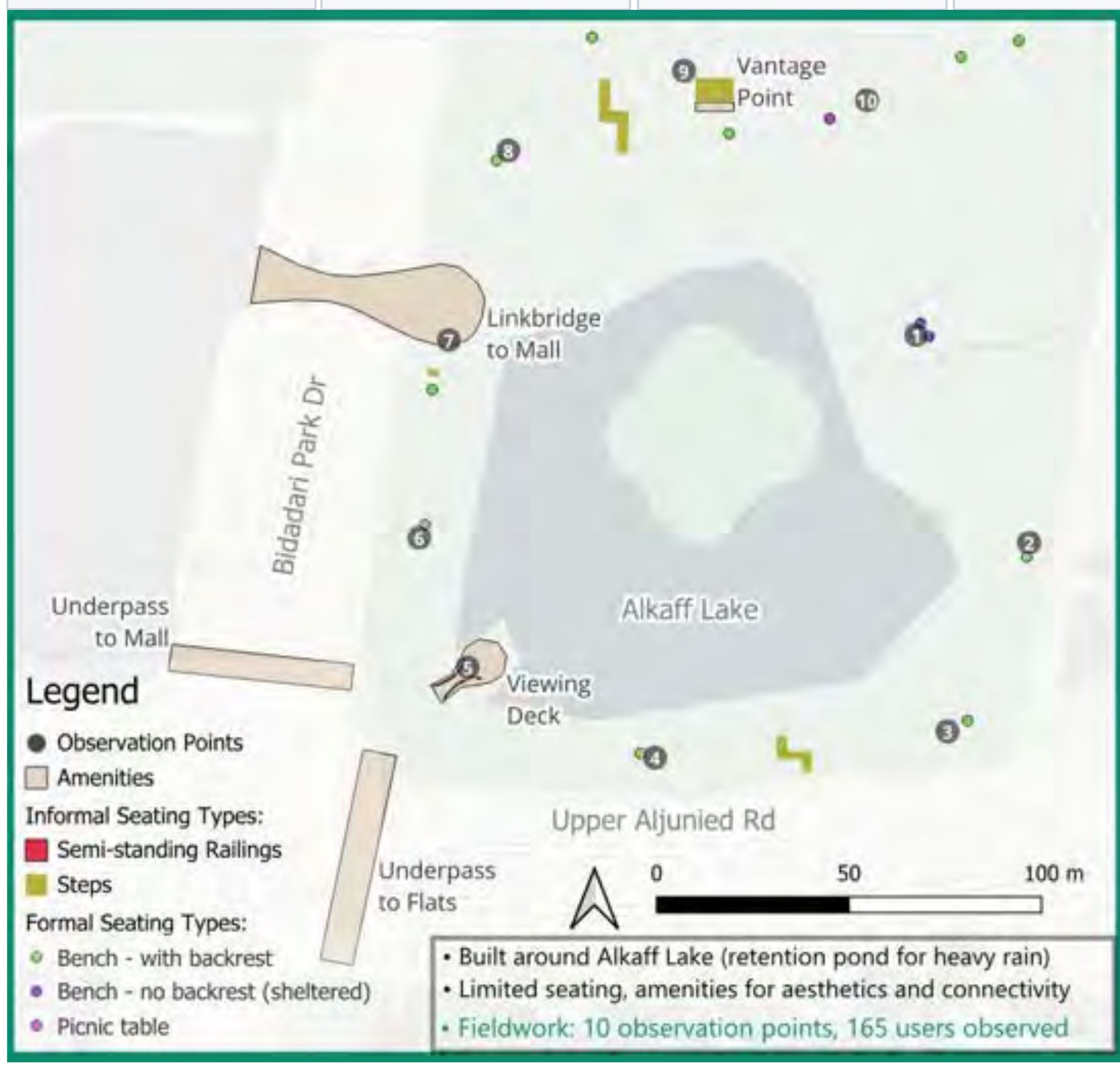
SRQ 2
Clustered to

Park User Profiles
Behaviour patterns that tend to occur together

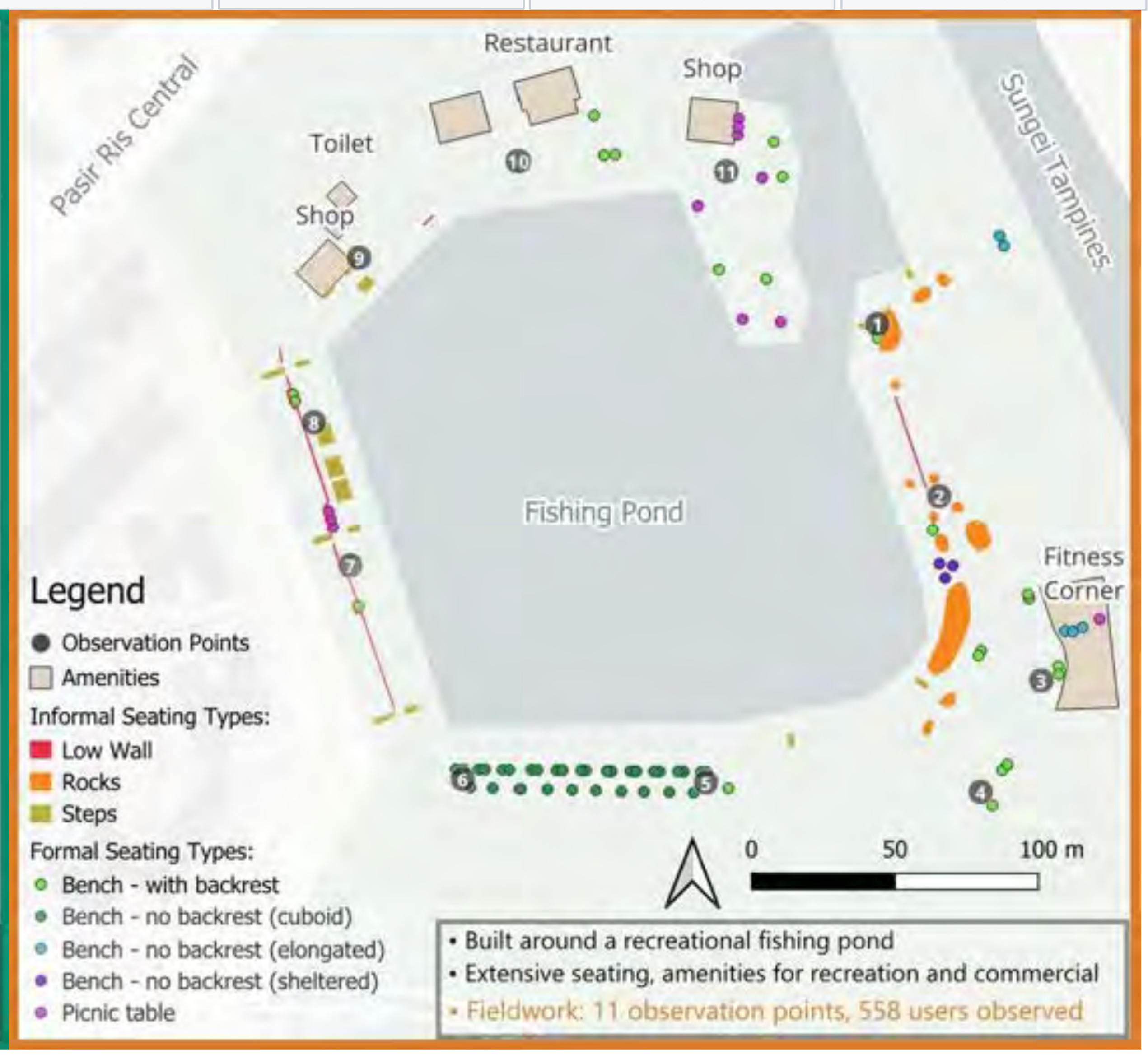
BIDADARI PARK | PASIR RIS TOWN PARK



View from point 5 (Alkaff Lake) · View from point 4 · View from point 10 · Locations of both parks · View from point 9 (fishing pond) · View from point 8 · View from point 10



- Built around Alkaff Lake (retention pond for heavy rain)
- Limited seating, amenities for aesthetics and connectivity
- Fieldwork: 10 observation points, 165 users observed



- Built around a recreational fishing pond
- Extensive seating, amenities for recreation and commercial
- Fieldwork: 11 observation points, 558 users observed

METHOD

Field studies · May 2026

Stationary Behaviour
Not moving with a micro-destination in mind (e.g. people-watching, resting, static exercise).

Sensor Standardisation
All instruments tripod-mounted at ~1.1 m height, ~10 min per point.

Users Observation
Using a customised web-app to record users' locations and behaviour types.

Temporal Sampling
2 day types (Weekday, Weekend), 3 time periods (AM, NN, PM)

SRQ 1 SENSORY ENVIRONMENT | BIDADARI | PASIR RIS

SOUND

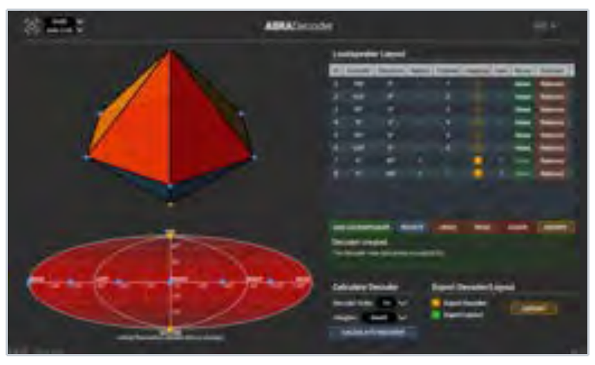
Zoom H3-VR
4-capsule ambisonic recorder

OUTPUT METRIC
Decibels · Sound Index (−1 anthropogenic ... +1 natural)

COLLECTION & PROCESSING

1. **RECORD** 360° B-format (SN3D), ~10 min at 1.1 m → four spatial vectors (W, X, Y, Z).
2. **DECODE** REAPER + AIIRADecoder: 4-channel B-format → six 60° horizontal sectors.
3. **CLEAN** Split to six mono files · resample to 16 kHz · trim to a uniform 8 min.
4. **CLASSIFY** YAMNet (521 categories) analyses each segment and gives it a score from natural (1) to anthropogenic (-1).

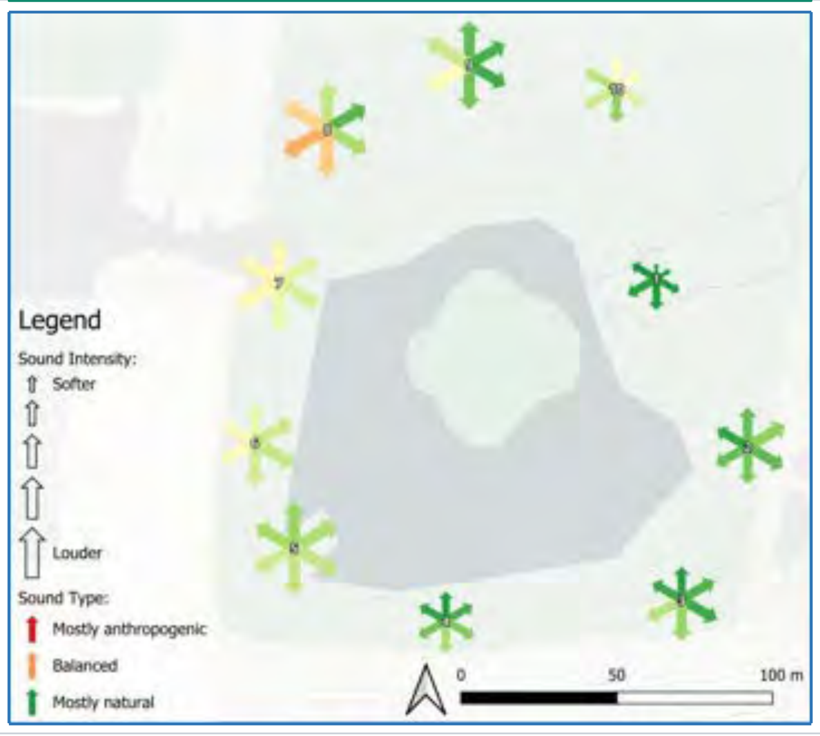
DATA PROCESSING SOFTWARE

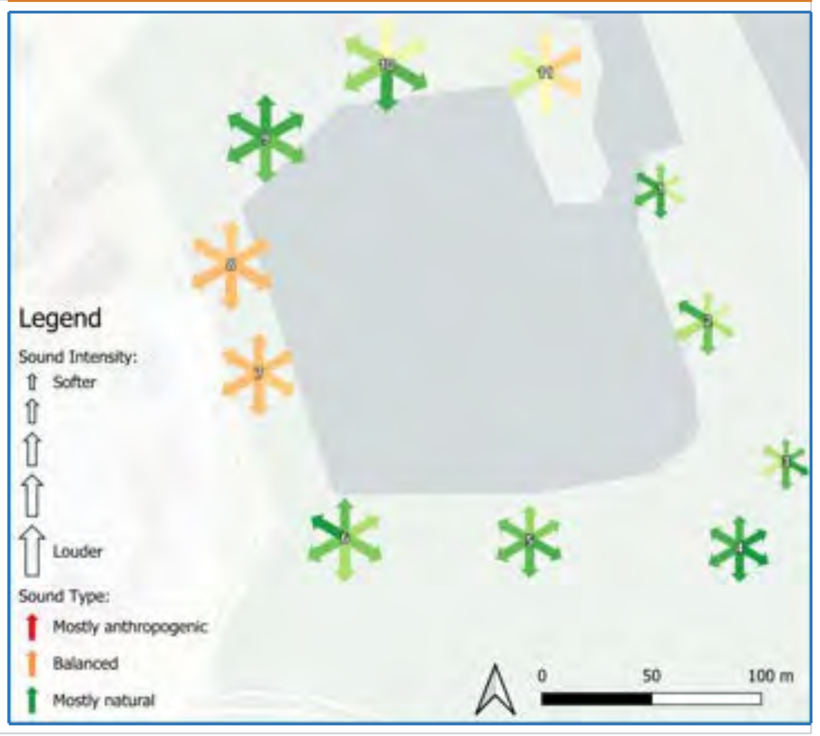


REAPER + AIIRADecoder — B-format decoded into six 60° sectors

WHAT THE MAPS SHOW

- Bidadari has a mostly natural soundscape, except point 8 by the road.
- Pasir Ris has a varied soundscape - natural to the south-east, anthropogenic to the west.





THERMAL

Kestrel 5500
Portable weather meter

OUTPUT METRIC
Apparent Temperature (°C)

COLLECTION & PROCESSING

1. **RECORD** Air temperature, wind speed and humidity were recorded every 5s for ~10 min per observation point.
2. **AVERAGE** 8-min average, excluding first ~1min 50s (sensor stabilization) and final 10s (equipment handling).
3. **SCALE** Wind speed was scaled from 1.1m to 10m height, using power law $v_{10} = v_{1.1}(\frac{10}{1.1})^{\alpha}$ Based on Wang et al. (2023), α ≈ 0.3 for urban terrain.
4. **COMPUTE** Apparent Temperature was calculated as a combined metric for outdoor thermal comfort (Steadman, 1994).

APPARENT TEMPERATURE

$$AT = T_a + 0.33P - 0.70v_{10} - 4.00$$

$$P = \frac{rh}{100}\left(6.105e^{\frac{17.27 \times T_a}{237.7 + T_a}}\right)$$

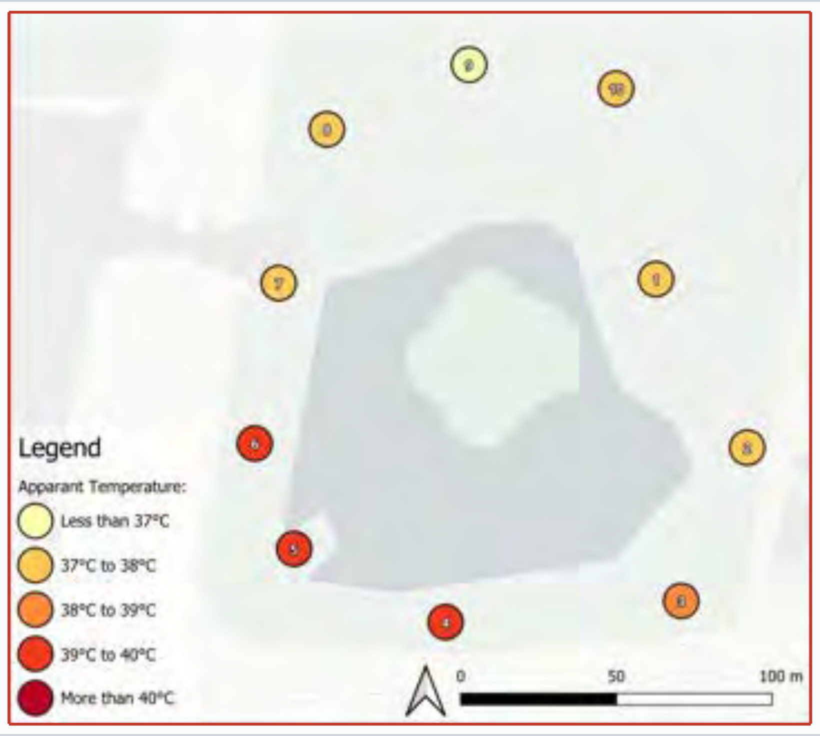
Where:
AT = Apparent Temperature (°C)
T_a = Air Temperature (°C)
P = Water Vapour Pressure (hPa)
v_{10} = Wind speed at 10m height (m/s)
rh = Relative humidity (%)

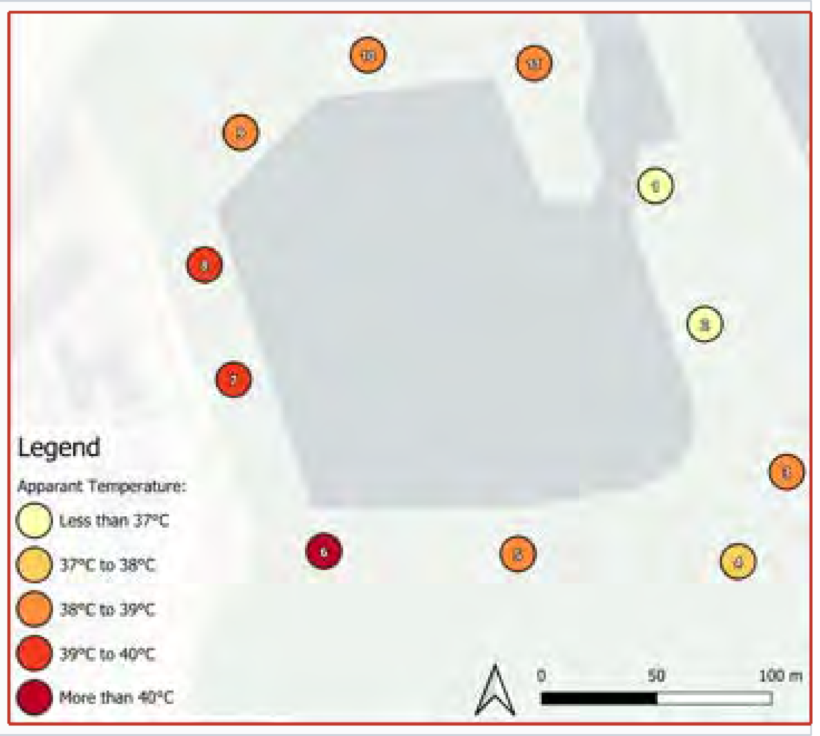
(Steadman, 1994),
(Australian Government Bureau of Meteorology, 2010)

WHAT THE MAPS SHOW

Bidadari is warmer towards the south-west
- Points 4, 5, 6 above 39°C

Pasir Ris is warmer towards the west
- Point 6 above 40°C, points 7, 8 above 39°C





VISUAL

Insta360 X3
360° panoramic camera

OUTPUT METRIC
Green View Index, GVI (%)

COLLECTION & PROCESSING

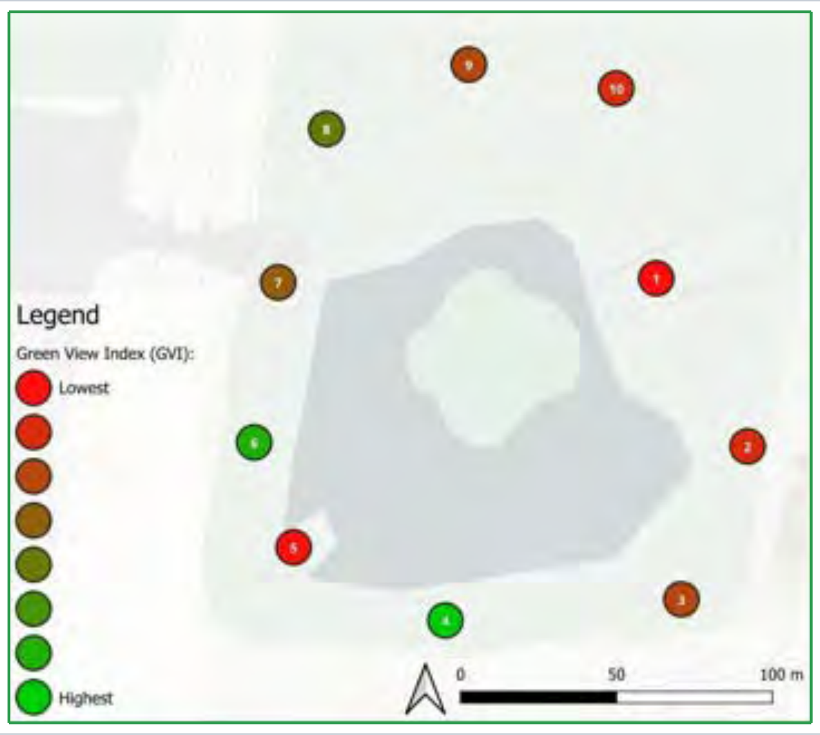
1. **CAPTURE** 360° equirectangular panorama at each node, before every session.
2. **SEGMENT** Python script isolates vegetative pixels, returning % greenery.
3. **CORRECT** De-amplification removes the centre-weighting of 360° projection.
4. **INDEX** Green View Index per node, averaged across the six sessions.

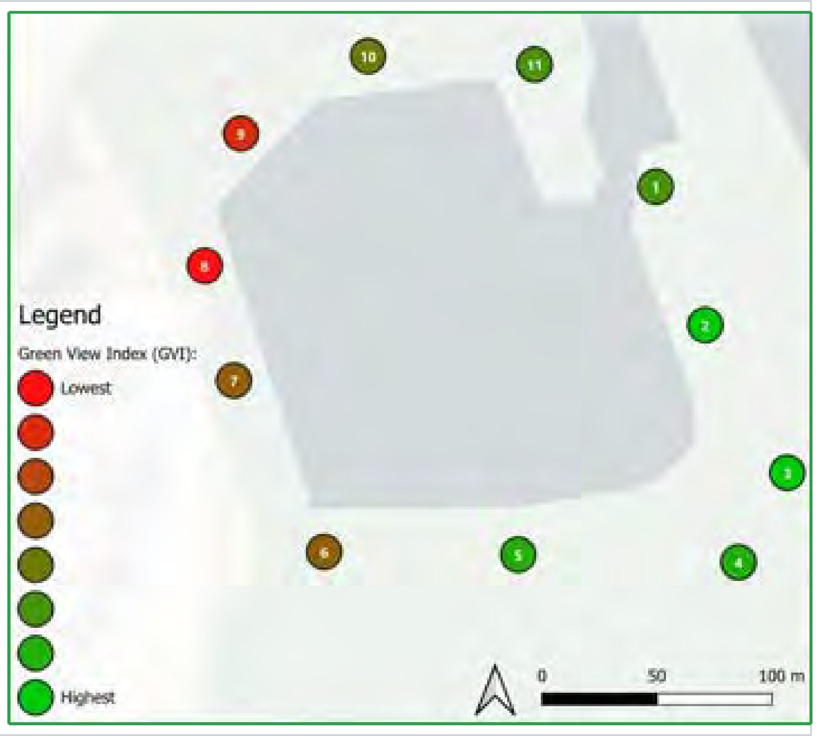
FROM THE FIELD

Example 360° equirectangular panorama — the GVI source image

WHAT THE MAPS SHOW

- Bidadari has an alternating mix of higher GVI (points 4, 6) and more paved-up areas (1, 2, 5).
- Pasir Ris has higher GVI towards the south-east (points 2, 3, 4, 5) and is more paved up towards the northwest (points 8, 9).





SMELL

Human Nose
Researchers' perceptual ratings

OUTPUT METRIC
Smell Intensity (1–5)
Smell Pleasantness (1–5)
Smell Duration
Smell Type

COLLECTION & PROCESSING

1. **RATE** Smell intensity and pleasantness each scored 1–5 by researchers' perceptions.
2. **NOTE** Smell duration recorded as continuous or intermittent, with smell type descriptors.
3. **GROUP** Smell type descriptors grouped into three macro-categories.
4. **BASELINE** NIL smell if intensity 1 and pleasantness 3 → 79 out of 126 sessions (neutral baseline)

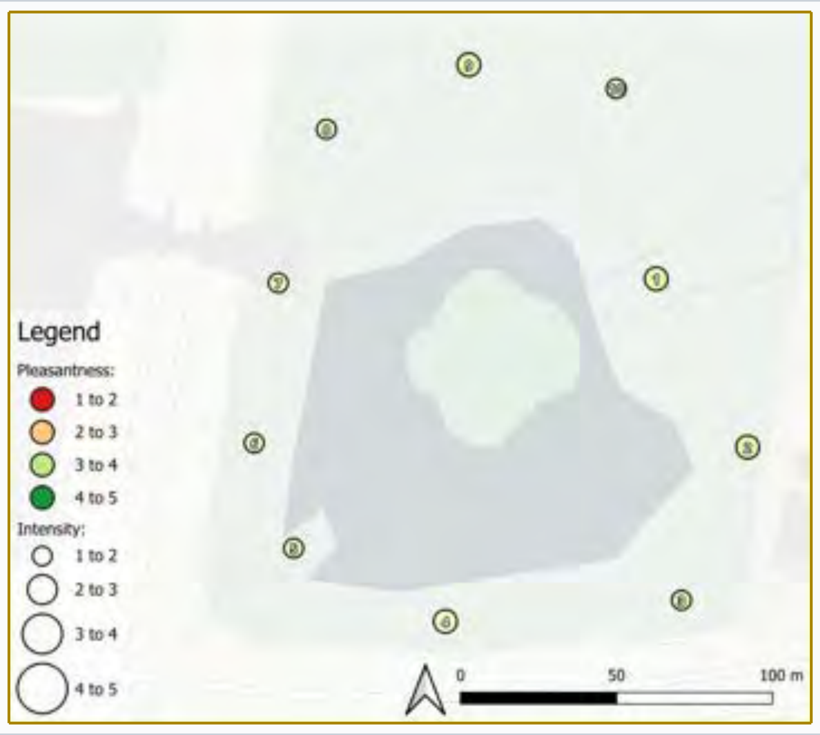
SMELL TYPE CATEGORIES

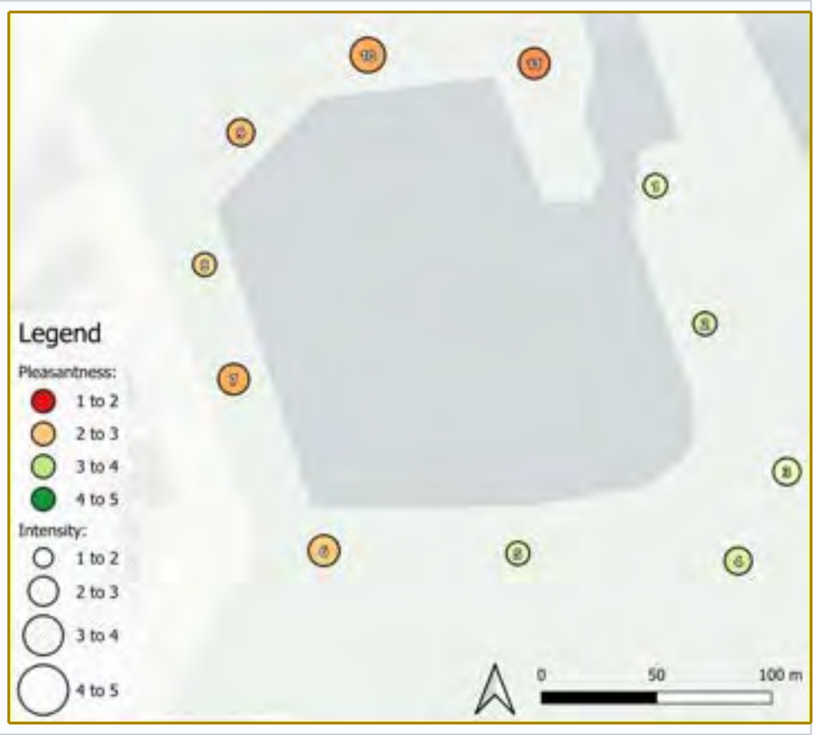
Anthropogenic	E.g. fishy (from fishing pond), cigarette smoke, BBQ food
Naturalistic	E.g. grassy, leafy, flowery, wet-earth
NIL	No discernible smell (intensity 1, pleasantness 3)

WHAT THE MAPS SHOW

Bidadari has mostly homogeneous and neutral smells throughout
- Points 5, 6, 7, 8, 10: NIL smell

Pasir Ris has more intense and unpleasant smells towards the northwest
- Points 7, 10, 11: intensity > 2, pleasantness ≤ 2





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Multi-sensory Evaluation of Urban Park Users' Stationary Behaviour

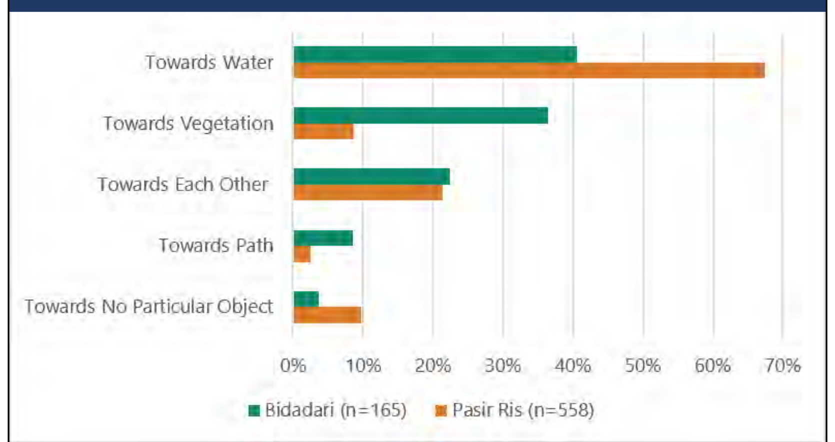
Chris-Duncan Allaix · Song Keat Tan · Inhwan Shin Supervised by: Dr. Sarah Chan MUSPP Master's Research Project 25/26 Singapore University of Technology and Design

SRQ 2 UNDERSTANDING STATIONARY BEHAVIOUR

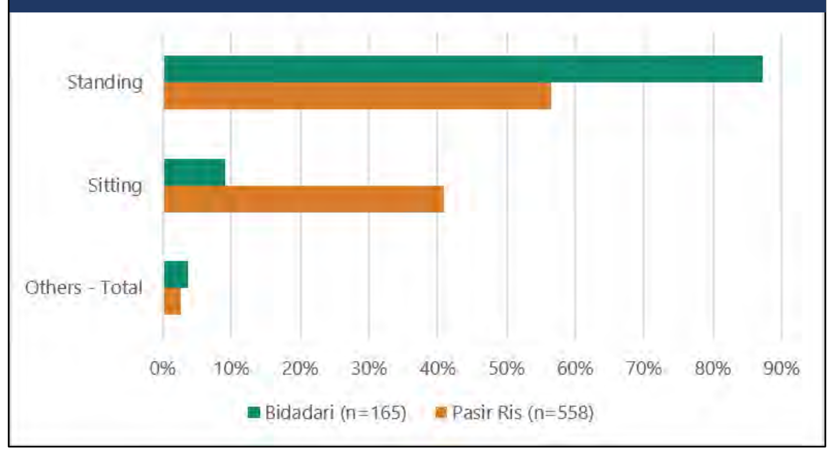
ACTIVITIES	Bidadari (n=165)		Pasir Ris (n=558)	
	Count	% of Total	Count	% of Total
In Conversation	101	61.2%	272	48.7%
Observing/ People Watching	88	53.3%	318	57.0%
Resting/ Relaxing	57	34.5%	175	31.4%
Photography	24	14.5%	1	0.2%
Interacting with/ Observing Wildlife	23	13.9%	4	0.7%
Using Electronics	6	3.6%	51	9.1%
Mindful Exercise (e.g. tai-chi or similar)	5	3.0%	51	9.1%
Eating/ Drinking	0	0.0%	70	12.5%
Fishing	0	0.0%	251	45.0%
Others	31	18.8%	37	6.6%

Note: Each person may be doing more than one activity. Thus, this section does not sum to 100%.

FACING DIRECTIONS/ OBJECTS

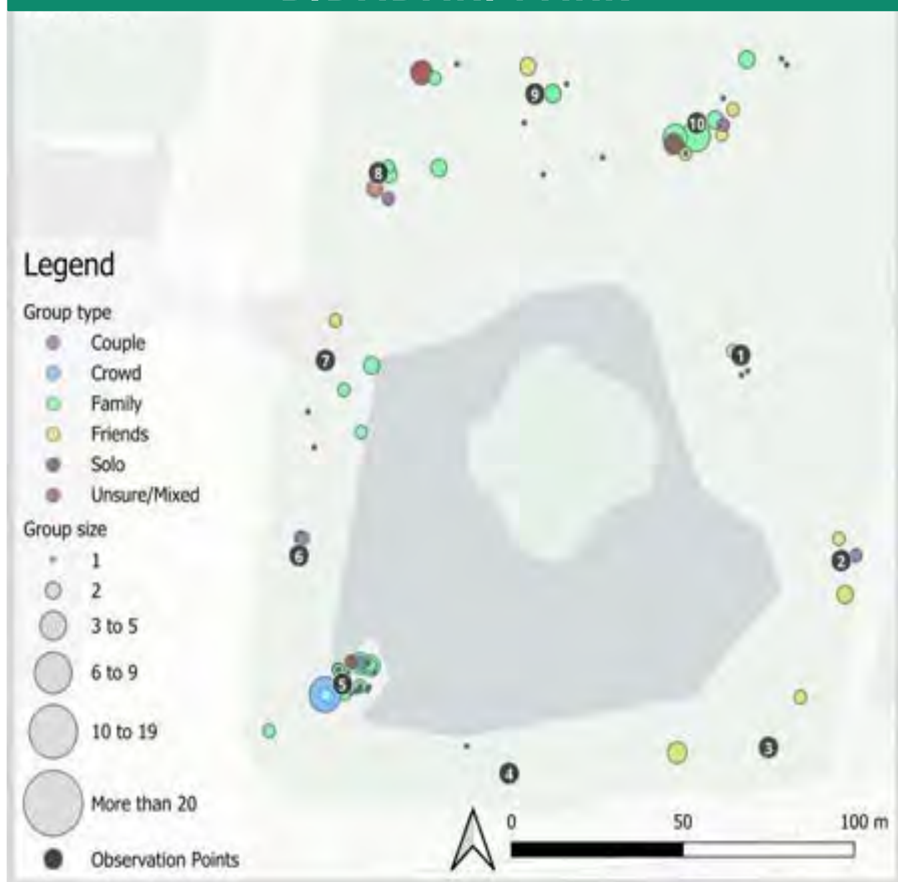


POSTURES

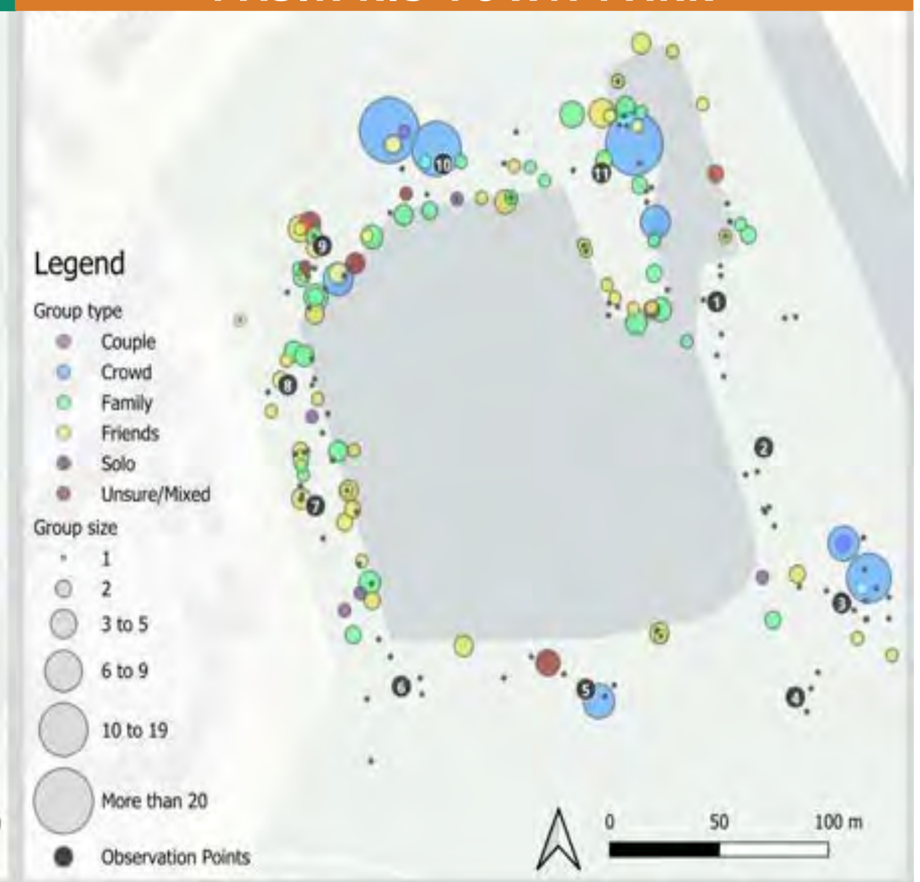


GROUP TYPES & GROUP SIZES

BIDADARI PARK

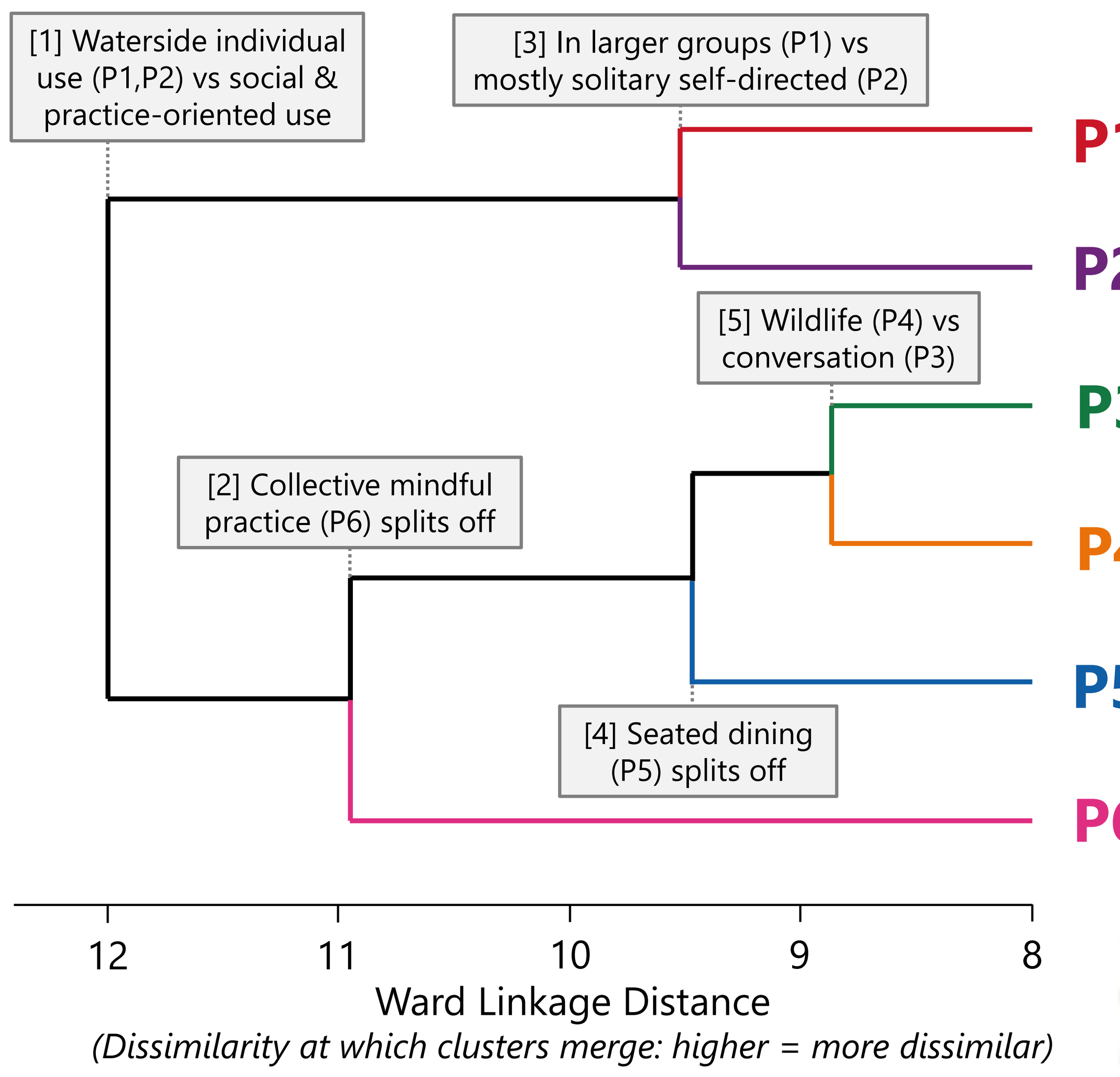


PASIR RIS TOWN PARK



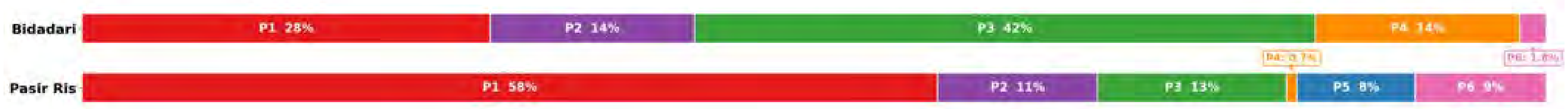
SRQ 2 CLUSTERING BEHAVIOUR → PARK USER PROFILES

WARD DENDROGRAM OF THE CLUSTERED PARK USER PROFILES



	Park User Profiles	Activities	Posture	Facing Object / Direction	Group Type
	P1 Waterfront Watchers n = 372	Fishing 64%, People-watching 76%	–	Towards water 92%	–
	P2 Self-Directed Users n = 84	Using electronics 44%, Exercising 31%	Sitting 58%	–	Solo 87%
	P3 Socialisers n = 142	In conversation 82%	Standing 77%	Towards each other 54%	–
	P4 Wildlife Appreciators n = 27	Interacting with wildlife 100%	Standing 89%	Towards vegetation 59%	Family 59%
	P5 Diners n = 45	Eating/drinking 100%, In conversation 100%	Sitting 100%	Towards each other 100%	Crowd 91%
	P6 Mindful Practitioners n = 53	Mindful exercise 94%	Standing 100%	No particular object 64%	Crowd 74%

PARK USER PROFILE COMPOSITION BY PARK



SRQ 3,4 UNCOVERING THE DRIVERS OF PARK USER PROFILES

Statistical Tests:
- *Multinomial Logistic Regression for common profiles (P1, P2, P3)*
- *Bivariate Analysis for park-specific profiles (P4, P5, P6)*

	Park User Profiles	NON-SENSORY: Spatial	NON-SENSORY: Temporal	NON-SENSORY: Demographic	SENSORY: Sound	SENSORY: Thermal	SENSORY: Visual	SENSORY: Smell
Bidadari *(P1 – NA due to baseline comparison with P2, P3 for regression modelling) (P5, P6 – NA due to limited sample size for Bidadari)*	P2 Self-Directed Users			Age: 40-60	Softer			
	P3 Socialisers		Time Period: PM		More naturalistic			
	P4 Wildlife Appreciators	West Zone	Time Period: PM		Louder, more anthropogenic			
Pasir Ris *(P1 – NA due to baseline comparison with P2, P3 for regression modelling) (P4 – NA due to limited sample size for Pasir Ris)*	P2 Self-Directed Users	(Avoid North-East Zone)	Day Type: Weekday	Gender: Female	Softer		More visual greenery	
	P3 Socialisers	North-West Zone	Day Type: Weekday		More naturalistic	Lower Apparent Temperature	More visual greenery	
	P5 Diners	North-West Zone	Time Period: PM		Louder, more anthropogenic			
	P6 Mindful Practitioners	South-East Zone	Time Period: AM	Age: Above 60 Gender: Female	Softer	Lower Apparent Temperature	More visual greenery	Continuous, naturalistic

END CONCLUSION

KEY INSIGHTS

SRQ 1 Describing urban parks' sensory environments
- **Sensorial environment** varies considerably across the 2 parks
- Most sensorial dimensions are not strongly correlated with each other

SRQ 2 Understanding and clustering stationary behaviour
- Some activities are **park-specific** *(E.g. Bidadari – observing wildlife, Pasir Ris – fishing)*
- Diverse co-occurring behaviour types can be grouped/ clustered into user profiles

SRQ 3 Non-sensory factors vs the sensory environment
- Multiple non-sensory & sensory factors are associated with various user profiles
- For non-sensory, **temporal factors** are the most significant
- For sensory, **auditory factors** are the most significant, but causation is unclear *(E.g. P2 Self-Directed Users may be inherently quieter, P5 Diners may be noisier)*

SRQ 4 Naturalistic vs anthropogenic sensory configurations
- Some user profiles are associated with multi-sensory configurations *(Pasir Ris only)*
- **P6 Mindful Practitioners** are associated with naturalistic sensory configurations across **4 senses**, suggesting that some user profiles have a strict threshold for sensory comfort

LIMITATIONS

Climatic and temporal bias
- Long manual fieldwork sessions of ~2.5 hours per time period /day type/ park
- Within each session, sensory environment and park users' behaviour patterns could vary across ~2.5 hours *(E.g. people may prefer to visit the park at 7.30am when it is cooler, instead of 9am)*

Subjective sensory data
- Manual assessments of odours and visitor' cardinal directions *(N, NE, NW, S, SE, SW)*, without specialized sensors

Limited analytical scope
- Limited to stationary behaviour, excluding surface type *(E.g. natural/ artificial ground)*

POTENTIAL FUTURE STUDIES

Temporal expansion
- Increase the number of sessions with simultaneous recordings per session, to reduce climatic/ temporal bias

Spatial expansion
- Reproduce the study in a temperate climate and study the same park throughout the seasons *(E.g. In a temperate climate, urban parks may not support the same activities in winter and in summer)*

More advanced odour sensors
- Use more advanced sensors (e.g. odour monitoring devices), for objective smell/ odour data collection

Expanded analysis of all park users
- Investigate the influence of surface types, wind, and sound directions, on all users' activities and postures

POLICY RECOMMENDATIONS

Differentiated sensory zoning
- Protect quiet inner sanctuaries, and increase canopy density for lower temperatures *(and more naturalistic environments)*
- To support activities which are more sensitive to sensory comfort *(E.g. mindful exercise)*

Buffering of commercial areas
- To buffer noisy food outlets from ecological corridors and meditation zones *(E.g. with spatial buffer and/ or dense planting areas)*

Flexibility of recreational uses
- Consider specific amenities/ sensory environments in response to changing needs *(E.g. Bidadari Park could set aside a mindful exercise zone, for ageing population in future)*