Sponge Interventions: A spacially informed decision-support framework for retrofitting **high-density transport urban precincts**

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The Problem: Flood-Prone Transport in High-Density Cores

(a) dry urban precinct

(a) during flood event

(c) contaminated water closup

Case of Thampanoor transport precinct: 15,000+ daily users. flooding frequency : 3 to 6 times per year during the monsoon season, Duration; 2 to 24 hours Water quality: BOD 31-54 mg/L (contaminated)

A dignity and mobility crisis

Thousands of workers, students, traders, migrants depend on Thampanoor railway station and bus terminal daily. During intense rainfall, contaminated water pools where they must walk. No alternative route. No choice.

Water is Black and Foul-odored

Stakeholder accounts document episodes of sewage-stormwater mixture covering walkways. BOD: 31–54 mg/L (heavy contamination). Direct pathogen exposure. Health risk.

Water Stagnates Here

Bowl-shaped local basin with gentle slopes (0–10°) , depressions traps runoff; blocked, undersized, misaligned drains mean that during a 1-in-25 year event the system fails

‘The call for sponge retrofits for flood resilience’

Concept of Sponge city


Wuhan Sponge Park Research + Visitor Center ,China/ Architects: UAO Design

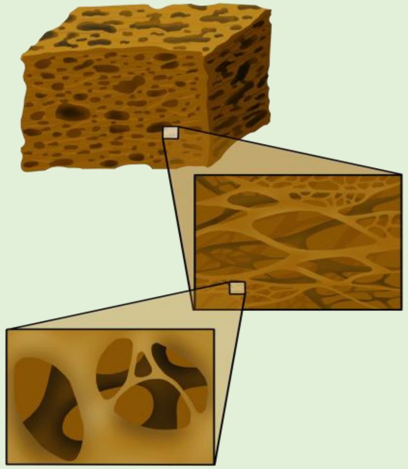
Benjakitti Forest Park,Bangkok, Thailand

The Dong'an Wetland Park, China

'Sponge City' is managing storm-water through increased infiltration, detention, storage, treatment, and drainage.

(Source: Resources, Environment and Sustainability (Journal, 2021))

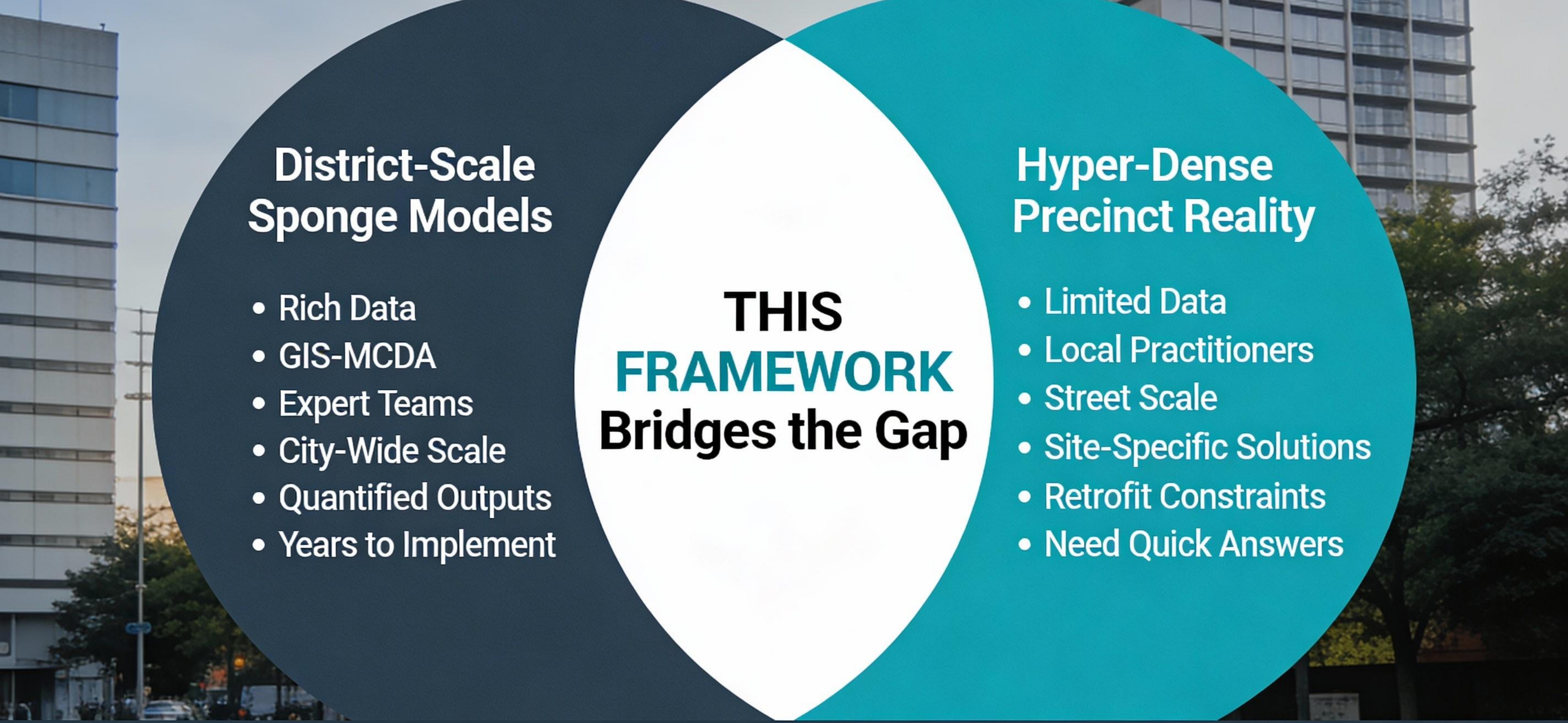
green approach

Conventional grey


Multiple benefits include:

- Reduced runoff peaks
- Pollutant removal (BOD, sediment)
- Groundwater recharge
- Urban cooling
- Greening (dignity dimension)



Qualitative + Site-Informed Decision Logic

Research question and objectives

How can a **qualitative**, spatially informed decision-support framework, built from **secondary spatial data, literature-based vulnerability** and **intervention typologies,** and **site-based observations**, guide the selection of **context-appropriate** sponge interventions for retrofitting a flood-prone, high-density transport urban precinct such as Thampanoor?

Objective 1 -stage 1

Identify key physical and functional factors contributing to flood and WASH vulnerability in dense transport precincts, drawing on international sponge-city and WSUD literature as well as secondary spatial and contextual data for Thampanoor.

Objective 2- stage 2

Evaluate how these vulnerability factors and related problem typologies manifest in the Thampanoor precinct through qualitative interpretation of secondary spatial layers and immersive site observations, including stakeholder experiences.

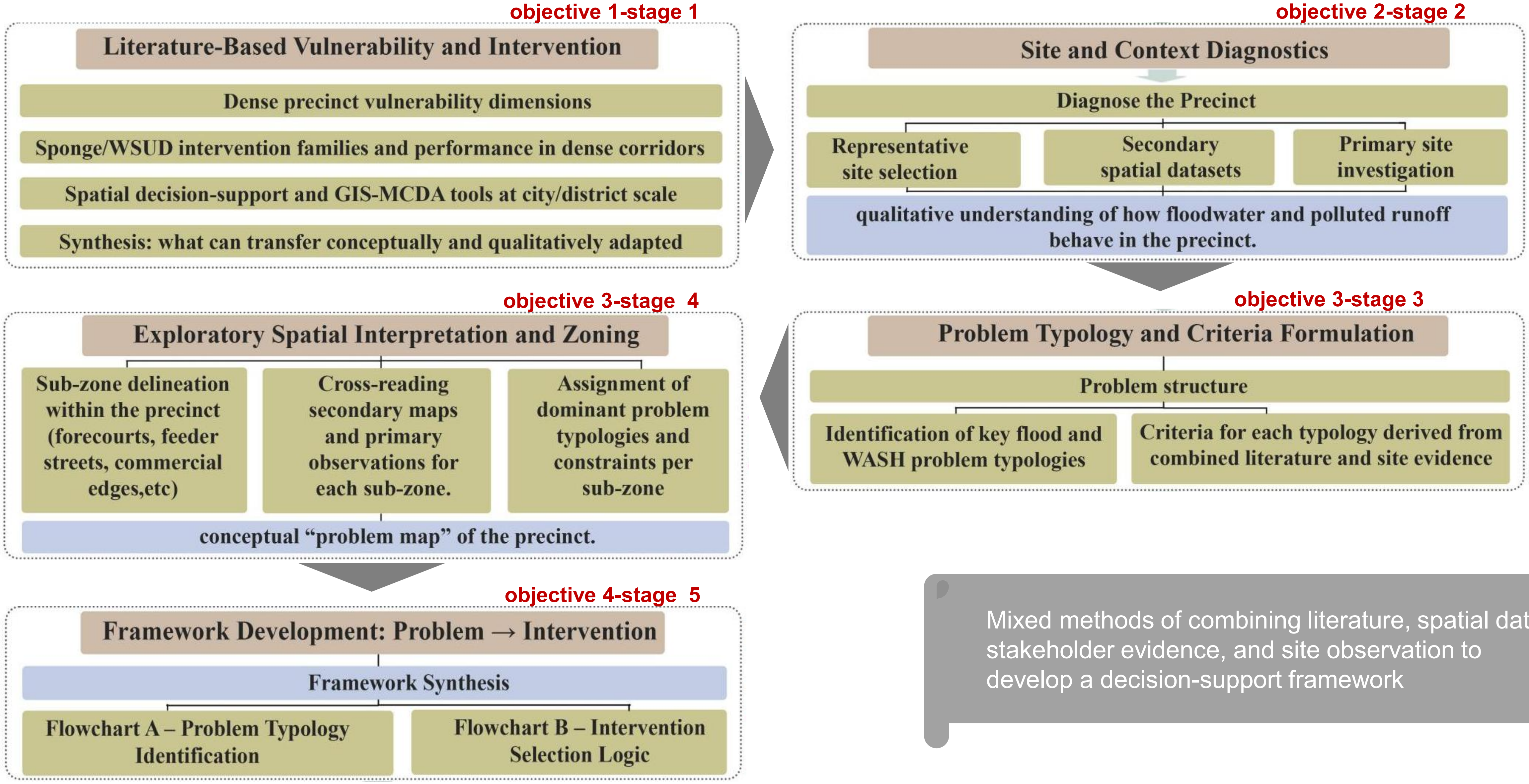
Objective 3- stage 3 and 4

Formulate a set of context-specific flood problem typologies and constraints for Thampanoor that can serve as a structured basis **for matching problems to sponge interventions**.

Objective 4- stage 5

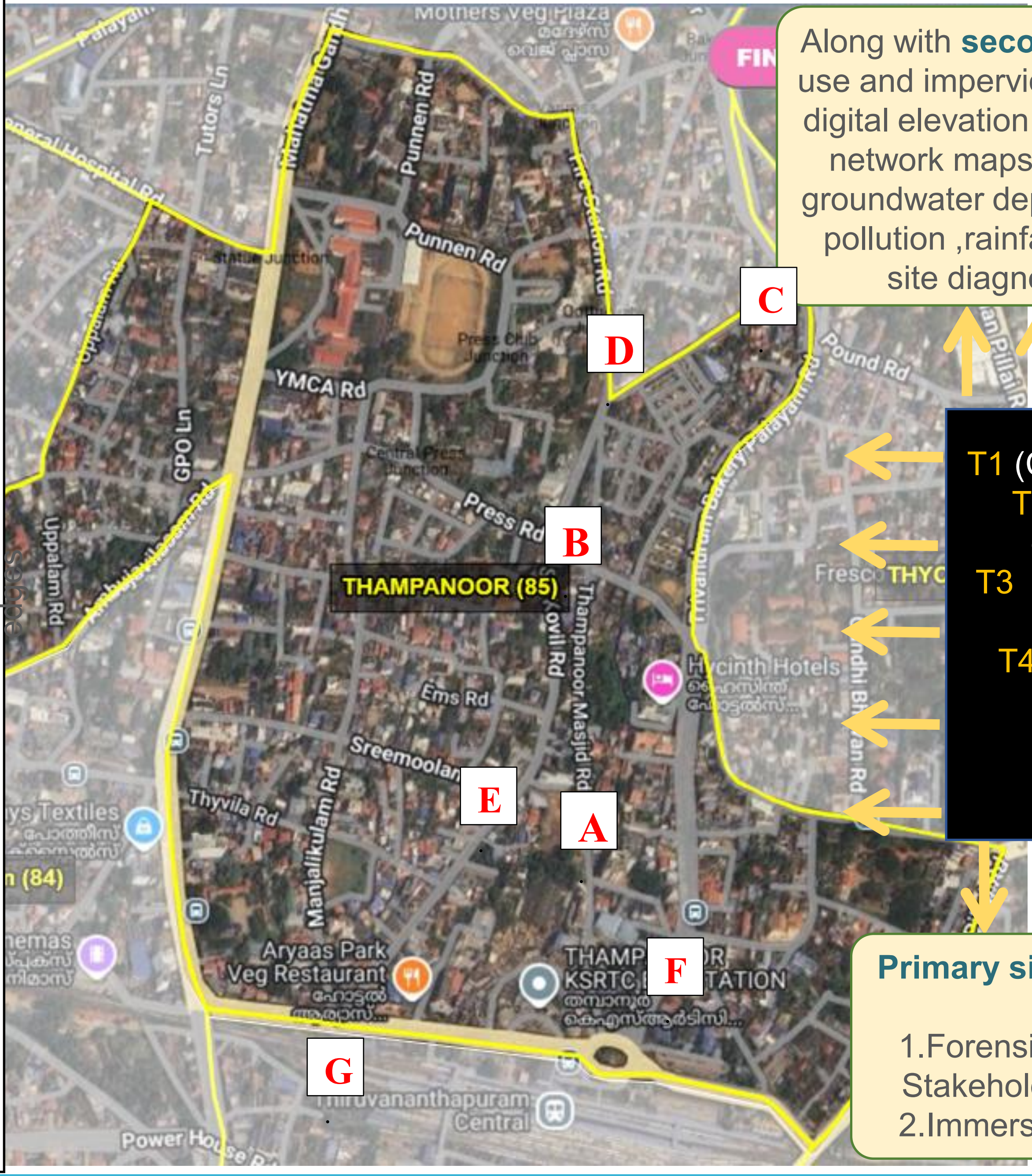
Develope a qualitative, spatially informed decision-support framework in the form of a problem–intervention suitability matrix and flowchart that can guide early-stage design and planning decisions for sponge retrofit strategies in dense transport precincts.

Research Methodology



Mixed methods of combining literature, spatial data, stakeholder evidence, and site observation to develop a decision-support framework

SUB ZONES :Feeder streets, roads, Residential lanes, commercial Streets, edges



Along with **secondary data** on land-use and imperviousness information, digital elevation and slope, drainage network maps, soil and lithology, groundwater depth, and BOD-based pollution ,rainfall dataand primary site diagnostic involved.

T1 (Chronic ponding)
T2 (High runoff contribution)
T3 (Polluted Runoff and Runoff)
T4 (Local Micro-ponding)
T5 (Spatial Constraint)

Primary site diagnostics using methods:
1.Forensic ground-Truthing & Stakeholder Evidence Matrix
2.Immersive Site Diagnostics

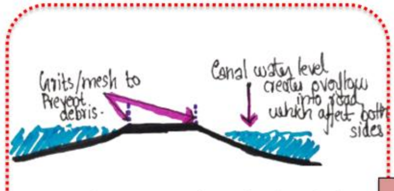
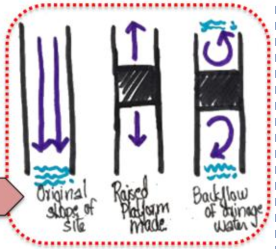


Fig showing impact of water flow due to high rised infrastructure on a natural drainage



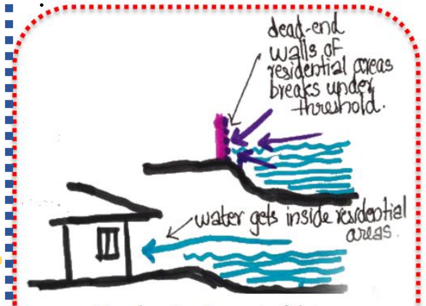


Fig showing impact of drinage water threshold

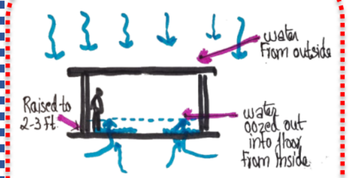


Fig showing a distinct factor of 'oozing' from within..(majorly seen in Masjid lane and chenkalchoola)

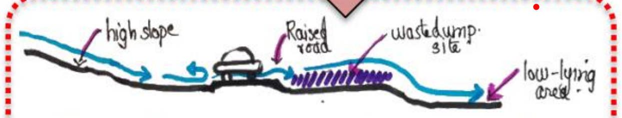
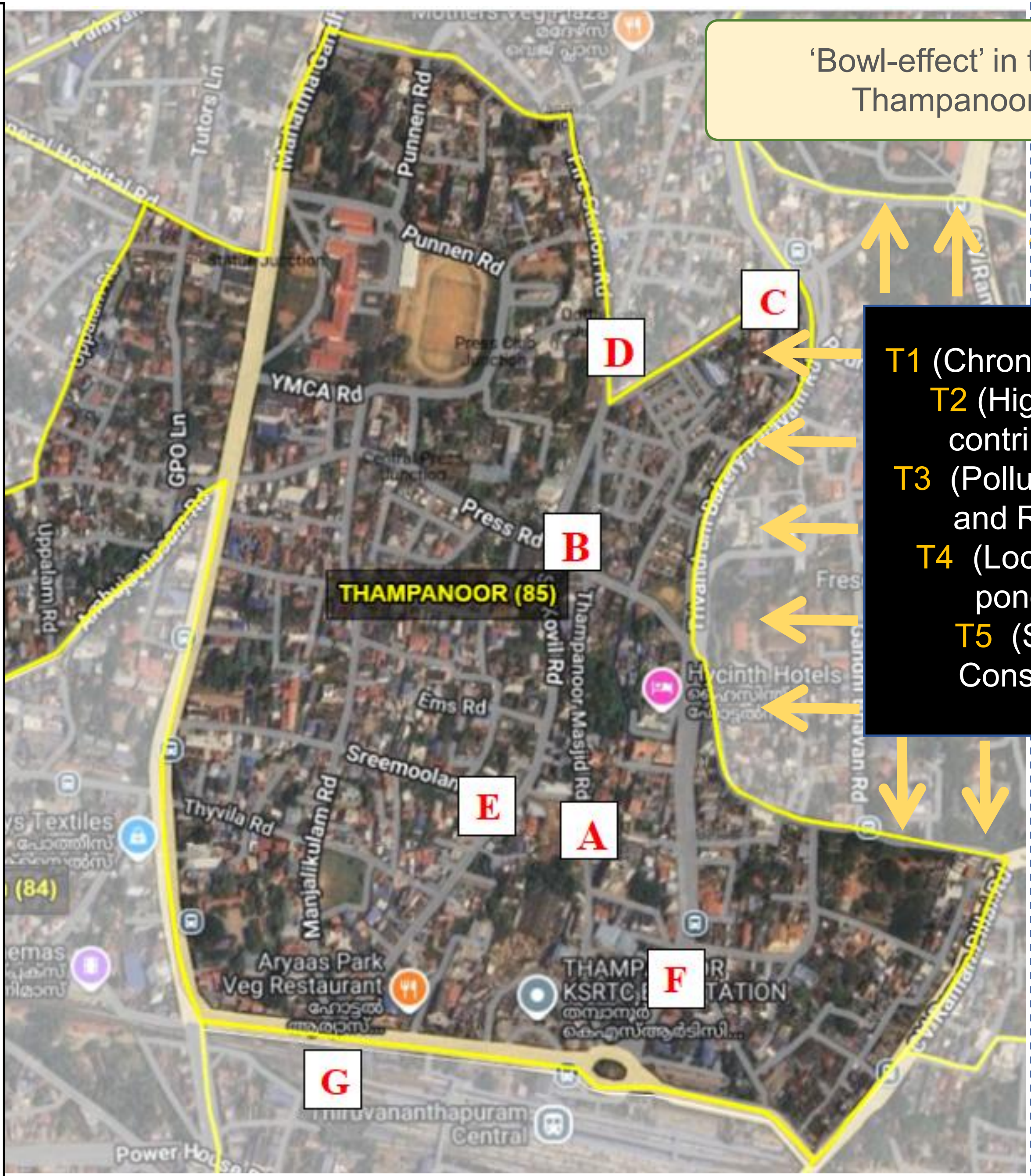


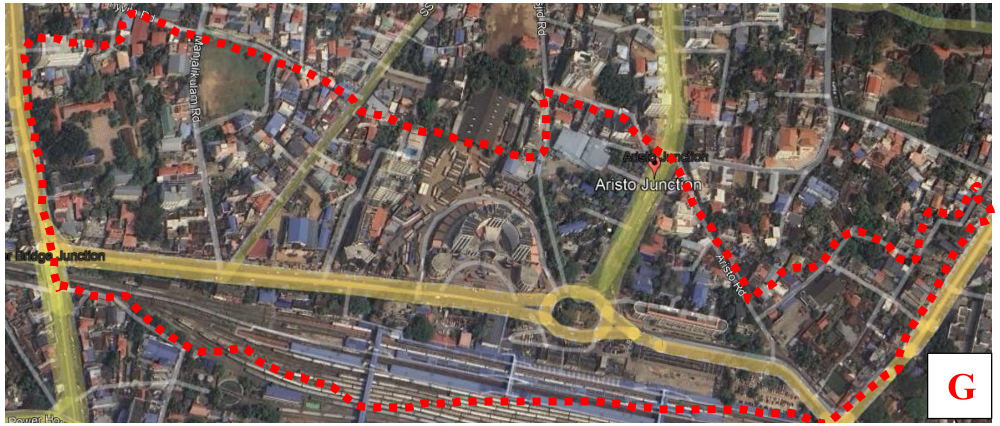
Figure showing impact of flow on low lying

SUB ZONE : Lower Thampanoor (KSRTC +Railway zone)



'Bowl-effect' in the lower Thampanoor zone

T1 (Chronic ponding)
T2 (High runoff contribution)
T3 (Polluted Runoff and Runoff)
T4 (Local Micro-ponding)
T5 (Spatial Constraint)



induced water-spread-out in rains ,not drained well below

Pluvial water logging condition

waters' path of natural draining is not made achieved

Grey infrastructures' in a way that,it itself prevents intented water draining

polluted and clogging those even creates unsafe conditions for pedestrians

the improper maintanance and failure of already established sponge interventions

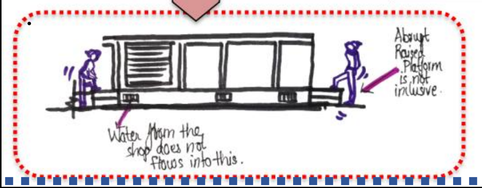
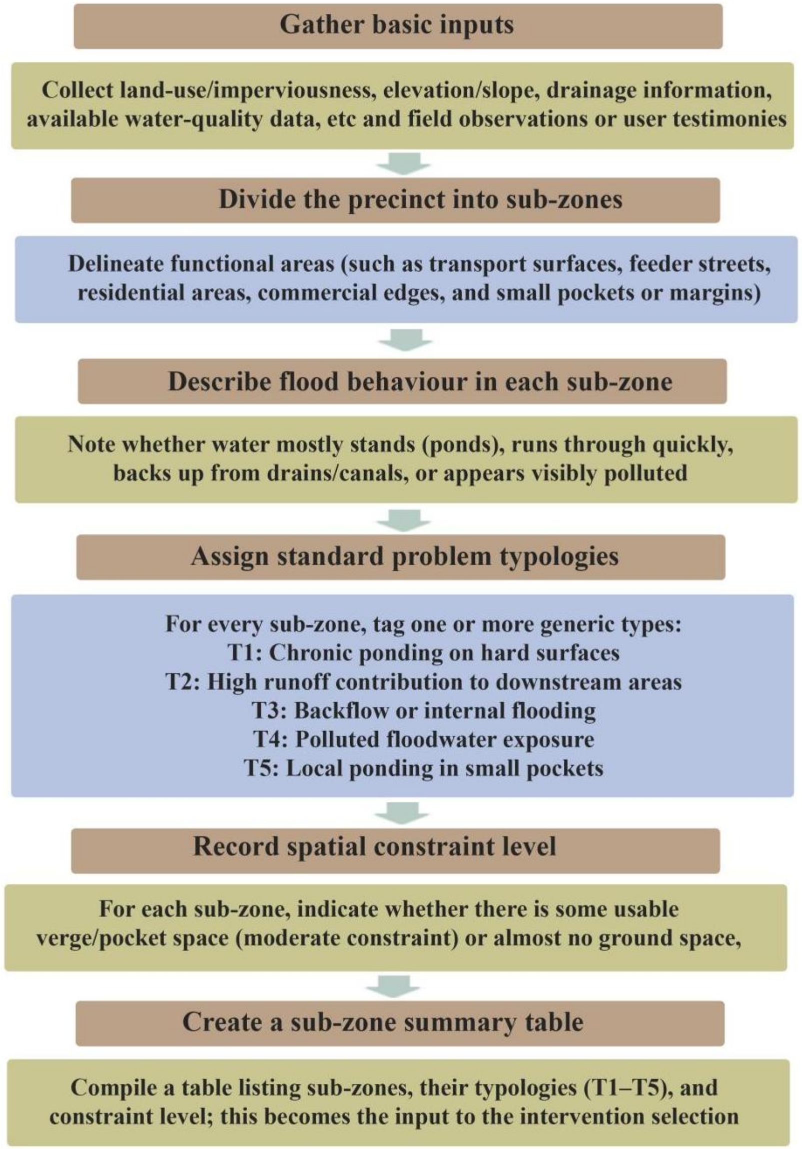


Fig showing the non-inclusivity , the drinage system creates. And the irregular placement of the elevated platforms that chanellize water irregularly

Summarized indicative findings

Sub-zone	Key spatial character	Observed flood behaviour	WASH-related and social issues	Dominant problem typologies
Z1 – KSRTC Bus Station Forecourt and Railway Frontage	Wide hardstand in front of KSRTC and railway buildings; almost fully paved with asphalt, concrete and platforms; low local gradients; dense pedestrian and bus traffic; drains present but often clogged / mismatched to flow paths.	**Frequent pluvial ponding water spreads across bus bays and walkways and drains slowly; evidence of black, debris-laden water and submerged manholes**	Commuters wade through contaminated water to reach buses and trains; safety risk from hidden manholes and traffic; short-term paralysis of public transport when depths increase.	**T1 Chronic ponding** on transport surfaces; polluted runoff at core node.
Z2 – Feeder Streets and Approach Roads (e.g., Masjid Road, Aristo Road, Bakery Junction approaches)	**Steeper streets connecting higher residential/commercial areas to the Thampanoor basin; sealed carriageways and narrow footpaths; surface flow directed toward the forecourt.**	**Rapid surface runoff toward the core; visible flow paths along kerbs; localised waterlogging at low points and at blocked side drains.**	Limited safe refuge for pedestrians during storms; runoff carries trash and pollutants from upper catchment into the basin.	**T2 Runoff contribution** from feeder roads to basin; local ponding at low points.
Z3 – Inner Residential Lanes and Canal-Edge Settlements (e.g., Rajaji Nagar, TTR-B Lane, Chembaga Nagar)	**Very narrow lanes with minimal drainage, adjacent to canal or low points; high building coverage; many informal adaptations (raised plinths, walls, plates); often at and below street level.**	**Backflow from canal and street into houses; water "oozing" up through floors; structural failures of buffer walls during peak events; long recession times.**	Indoor flooding, contamination, and loss of basic amenity; residents trapped at home; high exposure to black water and toxicity; psychological stress.	**T3 Polluted floodwaters** in residential thresholds; **hydrostatic pressure** and backflow; extreme spatial constraint.
Z4 – Commercial Edges and Shopfront Streets (e.g., SS Kovil Street, Masjid Road commercial strip)	Continuous shopfronts with minimal setbacks; raised plinths and steps; drains covered by slabs with narrow slots; high footfall and roadside vending.	**Localised flooding in front of shops; water retained against plinths and steps; flow paths disrupted by ad-hoc concrete works and platforms.**	**Contaminated standing water at entrances; accessibility conflicts (raised plinths protecting shops but excluding elderly/disabled); economic loss from repeated minor flooding.**	**T4 Polluted runoff** at commercial edges; spatial constraint at ground level.
Z5 – Public Spaces, Pockets and Margins (small open corners, verge fragments, under-used edges)	**Scattered small open areas, verge fragments, and residual corners along roads and near transport facilities; not continuous but present in pockets.**	**Temporary ponding during heavy rain where depressions exist; many spaces currently used for parking, storage or informal activities.**	Limited but valuable opportunities for local detention or treatment; if unmanaged, can become trash and mosquito hotspots.	**T5 Local ponding** with potential retrofit space; moderate spatial constraint.

How Designers Think Through It: ‘Problem Identification Flowchart’



*Flowchart A: Generic process for assigning flood/WASH problem typologies (T1–T5) and constraint levels (C1–C2) to precinct sub-zones**(Author generated)***

How Designers Choose: 'Sponge Intervention Logic Flowchart'

Take each sub-zone profile as input

For each sub-zone, start with its problem typologies (T1–T5) and constraint level, with basic information on slope, soil/groundwater, available width and structural capacity

Match typologies to intervention families

Use a small, fixed set of generic intervention families, for example:

F1–F3: Bioretention/raingarden strips, sunken belts, permeable panels for ponding **(T1)**
F4–F6: Permeable sidewalks, bioswales, intersection cells for runoff contribution **(T2)**
F7–F8: Threshold capture, small sumps/pumps for backflow **(T3)**
F9–F10: Treatment-oriented bioretention and filter strips for polluted water **(T4)**
F11: Pocket-scale raingardens or permeable patches for local ponding **(T5)**

Adjust for spatial constraint

If constraint is moderate, prefer ground-level families (F1–F11).

If constraint is extreme, shift emphasis to roof and façade families such as green roofs, rooftop raingarden trays and vertical greens (F12–F14).

Screen for physical feasibility

For each candidate family, quickly check that slopes, soil/groundwater, utilities and structure are within acceptable limits; drop options that clearly cannot work in that sub-zone.

Select a small recommended set per sub-zone

For each sub-zone, list 2–3 feasible and appropriate intervention families, with an indicative time horizon (short, medium, long term) based on how easily they can be implemented

Select a small recommended set per sub-zone

Summarise all sub-zones and their recommended intervention families into a representative form ;zone-level decision-support output of the framework.

*Flowchart B: Generic process for selecting sponge intervention families (F1–F14) based on typologies and constraints***(Author generated)**

Applied Example : Z1 KSRTC Bus Station Forecourt & Railway Frontage

Identified Problems:

- **T1 (Chronic Ponding on Transport Surfaces)** - Wide hardstand, low local gradients, clogged drains, frequent pluvial pooling
- **T3 (Polluted Floodwaters in Residential Thresholds)** - Black water mixing with runoff, exposure to commuters and staff

Site Constraints:

- 60m × 45m forecourt **(2,700 m²)** – heavily trafficked
- Minimal setbacks, underground utilities congested
- Cannot reduce traffic lanes or parking entirely
- Need to maintain bus manoeuvrability

DESIGN STORM RUNOFF VOLUME

Given:

- Area: 2,700 m² | Runoff coefficient (C): 0.95 | Rainfall (P): 461.9 mm *(Source : CRIS)*

Calculation:

Vtotal =C× A× P=0.95× 2,700× 0.4619=1,185 m3 *(Source: Rational Method (V = C·A·P)*

Intervention	Area/Length	Storage depth	Parameters	Volume	Source
(1) Permeable Pavement	1080m^2 (40% of forecourt)	75mm	pervious concrete+stone base voids	81 m^3	*https://www.perviouspavement.org/engineering.html*
(2) Bioretention Strips	120m x0.8m	0.5m depth,n=0.3 porosity	Engineering soil,surface ponding	14 m^3	*https://wiki.sustainabletechnologies.ca/wiki/Bioretention:_Sizing*
(3) Green Roof	200 m²	20 mm retention	Extensive sedum:50-60% rainfall retention	4 m^3	*https://livingroofs.org/storm-water-run-off/*

Combined solution result

Vretained=81+14+4=99 m3

Fraction of event runoff captured:

99/1,185≈ **8.4%**

Interpretation: Sponge infrastructure intercepts **~99 m³ of the 1,185 m³** event runoff at source, reducing ponding duration and improving water quality across the retrofitted areas.

Metric	Current State	Post-Retrofit
Ponding Duration	2–3 hours	20–30 minutes
Water Quality (BOD)	31–54 mg/L	15–20 mg/L (60% reduction)
Flood Risk (1-in-25 event)	Full forecourt inundated	<10cm residual depth on 5% of area
Commuter Safety	Black water exposure during rain	Clean, drained surfaces
Co-benefits	None	Greening (135 m² vegetation), temp reduction, infiltration, habitat

The sponge retrofit is not a substitute for grey drainage but a front-end buffer: even an 8–10% interception of a design event is enough to reduce surcharge risk at critical nodes, strip pollutants at source and improve safety and comfort in the busiest public spaces

Given the construction, social and environmental costs of further hardening Thampanoor with heavier grey works low-disruption sponge retrofits are an efficient and multi-benefit complement.

Key improvement: From full forecourt inundation → minimal residual flooding with faster drainage, improved water quality, and operational safety for commuters.

From Concept to Practice

This framework translates abstract **Water sanitation and Hygiene + climate resilience concepts** into **site-reading logic** that architects and planners can teach in studios and use in practice. Enabling retrofitting of everyday spaces—not iconic gestures—where people actually move, work, and access water and sanitation. For the Global South, this approach offers a transparent, repeatable decision pathway for solving real problems.

Scaling of the Framework Forward

"How do we adapt this framework to other transport hubs in India and the Global South?"

"How do we integrate feedback loops to measure sponge performance and refine design?"

"How do we build cost-benefit cases for municipal adoption and phased implementation?"

"How do we bridge this framework with existing Water and Saniattion ,Hygiene governance structures?"

Thank You

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