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A PED-Oriented Design Framework for Low-Carbon Regeneration of Historic Street Spaces with AI-Assisted Design

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1 RESEARCH BACKGROUND

- Historic street spaces carry cultural memory, public life, and everyday mobility.
- Low-carbon regeneration is constrained by dense built fabric, narrow sections, heritage regulations, fragmented ownership, and local practices.
- Positive Energy District (PED) theory provides district-scale guidance for energy transition.
- However, PED principles are difficult to translate directly to the scale of historic streets.
- This study proposes a PED-oriented and AI-assisted design framework for historic street regeneration.

Research question

How can district-scale PED principles guide low-carbon regeneration at street scale?

Study scope

A conceptual design framework with reference-case translation. Energy performance requires field validation.

2 CORE METHODS

2.1 Theory-led synthesis

Structured synthesis across four domains.

PED theory	Low-carbon urban regeneration	Historic street / public-space design	AI / governance support

2.2 Mechanism coding matrix

Organize knowledge into a structured matrix.

Problem → Scale → Intervention → Observable outcome → Heritage / governance constraint

2.3 Screening criteria

Select applicable strategies for historic streets.



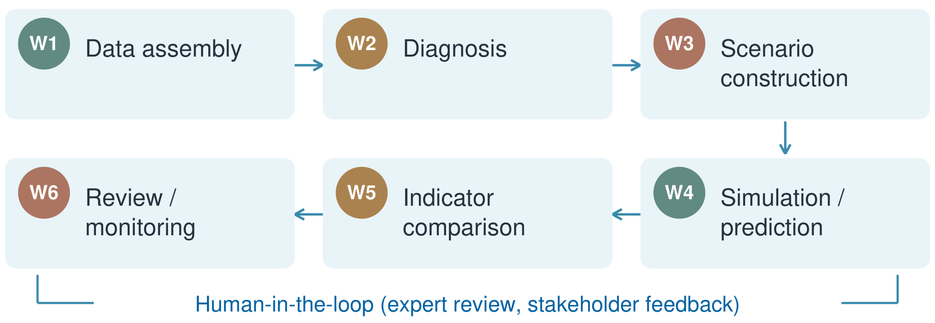
2.4 Cross-mapping and consolidation

Translate insights into six design dimensions.

Space	Mobility	Microclimate
Building-Energy	Operation	Governance

2.5 AI-assisted design workflow (human-in-the-loop)

Six proposed stages, with human review throughout.



2.6 Reference case structure analysis

Conceptual renewal mechanisms and transfer focus.

Shanghai Xintiandi

Adaptive reuse → Pedestrian-commercial restructuring → Spatial activation

Commercial reuse as a reference for street-space activation.

Jeonju Hanok Village

Heritage revitalization → Collaborative governance → Community continuity

Heritage continuity as a reference for community-oriented regeneration.

3 KEY RESULTS

PED-Oriented Design Framework for Low-Carbon Regeneration of Historic Street Spaces

I AI-Supported Cultural-Technical Enabling Layer

Proposed AI support for cognition, analysis, and feedback.

Sensing and monitoring	Scenario simulation	Computer vision / machine learning	Natural-language processing	Digital operations
Environmental data collection and dynamic detection	Multi-option comparison and performance prediction	Visual recognition, pattern mining, and feature extraction	Public opinion interpretation and collaborative decision support	Continuous monitoring, alert response, and adaptive control

II Low-Carbon Regeneration Strategy Layer for Historic Streets

Six integrated design dimensions.

S1 Spatial Reallocation Interface optimization, mixed functions, and more public space	**S2 Low-Carbon Mobility** Pedestrian priority, integration of walking, cycling, and public transport	**S3 Green-Blue Microclimate** Green-blue networks, shading and ventilation, thermal environment improvement
S4 Building-Energy Interface Existing-building upgrades, distributed energy, and low-carbon retrofit	**S5 Circular Operation** Resource circulation, low-carbon maintenance, and life-cycle management	**S6 Participatory Governance** Multi-actor collaboration, community co-management, and adaptive negotiation

III District-Scale PED Transition Targets

Proposed target dimensions; energy performance requires validation.

Demand reduction	Dynamic / virtual energy coordination	Climate adaptation	Cultural continuity	Long-term management
Lower energy demand and carbon emissions	Integration of distributed energy and flexible loads	Improved resilience and thermal comfort	Conservation and adaptive reuse	Continuous evaluation and adaptive governance

Candidate validation indicators

Spatial reallocation	• Pedestrian/public-space share • Active frontage ratio
Low-carbon mobility	• Walk/cycle/public transport share • Connectivity improvement
Green-blue microclimate	• Canopy/shade-area ratio • Permeable surface ratio
Building-energy interface	• Energy use intensity (EUI) • Retrofit coverage • Renewable/flexible-load potential
Circular operation	• Reuse/recycled material share • Waste diversion rate
Participatory governance	• Participation rate • Stakeholder diversity • Satisfaction score

Reference case comparison

Aspect	Shanghai Xintiandi	Jeonju Hanok Village
Renewal mechanism	Adaptive reuse; pedestrian-commercial restructuring; spatial activation.	Heritage revitalization; collaborative governance; community continuity.
Main risk	Displacement.	Commercialization and resident conflict.
Transfer focus	Public-space activation with attention to residents.	Community participation and cultural continuity.

Evidence limit: Reference cases only.
No confirmed positive energy performance is demonstrated.

4 CONCLUSION & FUTURE WORK

Key findings

- The study provides a traceable way to translate district-scale PED principles into street-scale regeneration strategies.
- The framework links spatial design, mobility, microclimate, building-energy interfaces, circular operation, and participatory governance.
- AI is proposed for diagnosis and scenario comparison. Final decisions remain with experts and stakeholders.
- PED-oriented design does not establish a positive energy balance. Field validation is still required.

Future work

- Field validation in more historic street districts.
- Before-after monitoring of street environment and use.
- Resident feedback and stakeholder evaluation.
- Microclimate and building-energy measurement.
- District-level energy assessment.