

Part II
Sustainable and Resilient
Infrastructure

Chapter 13

Co-creating Cities with AI and Digital Twins: A Multispecies Participatory Approach

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Abstract

Urban participatory design has expanded in recent years through digital tools, yet remains largely human-centred, overlooking the needs of non-human stakeholders. This paper presents a methodological framework that integrates ecological signals into participatory processes through a digital twin, enabling multispecies co-creation. The approach was tested in the GreenInCities Barcelona pilot site, where three complementary methods were applied: (i) vegetation analysis using NDVI values applied to drone imagery to assess greenery health, coverage, and typology; (ii) species monitoring through participatory observations and camera traps, generating heat maps of local fauna presence; and (iii) microclimate modelling combining AI simulations and environmental data to map thermal comfort conditions for non-humans. Early results demonstrate how these indicators, when embedded as interactive layers in the digital twin, informed participatory sessions and shaped concrete design strategies, such as bridging vegetation corridors, wildlife refuges, shading interventions, and lighting design adaptations. Beyond enriching co-analysis and co-design, the framework supports co-monitoring by allowing indicators to be updated and revisited over time, creating a feedback loop that sustains multispecies participation throughout the project lifecycle. In doing so, it establishes a replicable and scalable pathway for embedding non-human needs into urban planning and highlights the new role of humans as mediators and allies for other species through technology.

Keywords: *Cross-disciplinary innovations, Cognitive Cities, Urban planning and design, Digital twin, Co-creation*

Introduction

Participatory urban design has evolved significantly, from the community-driven advocacy of Jane Jacobs¹ and Arnstein's "Ladder of Participation"² to today's digitally enhanced processes that use GIS, VR, and AI to expand citizen engagement³. These tools have broadened opportunities for inclusion, yet participation remains largely human-centred: citizens are empowered, but only human citizens. In

¹Jane Jacobs, *The Death and Life of Great American Cities* (New York: Random House, 1961).

²Sherry R. Arnstein, "A Ladder of Citizen Participation," *Journal of the American Institute of Planners* 35, no. 4 (1969): 216–24, <https://doi.org/10.1080/01944366908977225>

³Junjie Luo et al., "Urban Digital twins for Citizen-Centric Planning: A Systematic Review of Built Environment Perception and Public Participation," *International Journal of Applied Earth Observation and Geoinformation* 143 (2025): 104746, <https://doi.org/10.1016/j.jag.2025.104746>

parallel, scholarship on urban ecology highlights the importance of biodiversity and multispecies interactions for resilience⁴. However, non-human life is often framed in utilitarian terms, as providers of ecosystem services, rather than as stakeholders with needs and vulnerabilities. Multispecies theorists such as Haraway⁵ and Tsing⁶, and recent debates in multispecies urbanism and justice⁷, argue for recognising cities as shared habitats shaped by more-than-human collaborations⁸. Despite these contributions, non-humans remain absent and underrepresented in urban participatory processes. At the same time, new digital tools, including GIS, VR, AI, and digital twins, have been introduced to expand participation by making complex data accessible and immersive⁹. These technologies allow non-experts to visualise information and explore scenarios, but they remain focused on human users and lack pathways to incorporate ecological signals into decision-making. This paper addresses that gap by presenting a framework in which ecological indicators, derived from vegetation analysis, wildlife monitoring, and microclimate simulations, are integrated into a digital twin environment. This approach makes the presence and wellbeing of non-human stakeholders visible and debatable within participatory processes. By translating ecological signals into shared design indicators, the framework redefines participatory urban design as a multispecies co-creation, where humans act not only as beneficiaries but also as allies and mediators for non-humans.

Methods for Non-human Participation

Non-human species cannot participate directly in design processes; their signals must be translated into indicators that can represent them in the co-creation process. The proposed methodological framework structures three methods with a data workflow starting from the signal to be collected and ending in its possible participatory use in the participatory phases of co-analysis, co-design, and co-monitoring. In this framework, technology supports signals collection, interpretation, and visualisation to make ecological needs visible and understandable.

This framework was tested in the GreenInCities project¹⁰ Barcelona pilot site, a promenade near the Besòs river mouth. Since September 2024, biodiversity experts, technicians, students, citizens, and policymakers have engaged with this novel approach to co-analyse site conditions and co-design

⁴Marina Alberti, *Cities That Think Like Planets: Complexity, Resilience, and Innovation in Hybrid Ecosystems* (University of Washington Press, 2016).

⁵Donna Haraway, *The Companion Species Manifesto: Dogs, People, and Significant Otherness* (Prickly Paradigm Press, 2003).

⁶Anna L. Tsing, *The Mushroom at the End of the World: On the Possibility of Life in Capitalist Ruins* (Princeton University Press, 2015).

⁷Danielle Celermajor et al., "Multispecies Justice: Theories, Challenges, and a Research Agenda for Environmental Politics," *Environmental Politics* 30, no. 1–2 (2020): 119–40, <https://doi.org/10.1080/09644016.2020.1827608>

⁸Alberti, *Cities That Think Like Planets*, 221–240.

⁹Luo et al., "Urban Digital Twins for Citizen-centric Planning: A Systematic Review of Built Environment Perception and Public Participation," 2025.

¹⁰CORDIS, "GreenInCities," European Commission, December 21, 2023, <https://cordis.europa.eu/project/id/101139730>

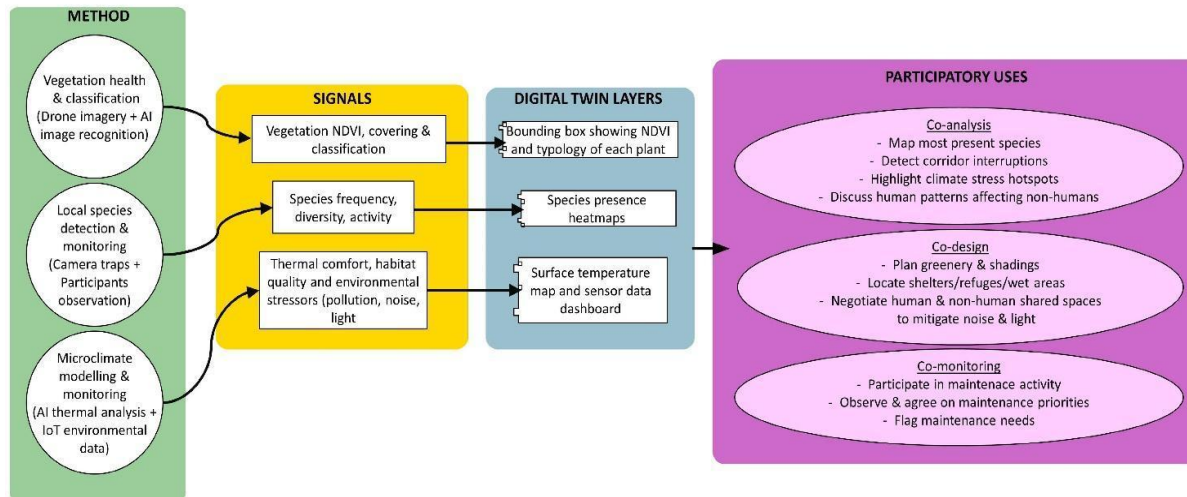


Figure 1: Methodological framework workflow.

interventions. While some sensor deployments remain pending due to administrative permits, digital twin of the site was successfully developed and initial results from vegetation analysis, species monitoring, and thermal modelling have already been integrated into participatory sessions.

Vegetation analysis

Local vegetation presence, health, and diversity affect the habitat conditions of local fauna and inform maintenance needs together with landscape choices. Automated collection of this data is performed through AI-based computer vision and machine learning algorithms that analyse and process drone imagery to classify vegetation by type and to calculate the normalised difference vegetation index (NDVI), a proxy for plant health. The data, when integrated as layers in the digital twin, provide a quantitative picture of vegetation health and presence across the pilot site, making possible to estimate both the condition and percentage coverage of greenery. In GreenInCities, NDVI values and plant typologies were integrated in the digital twin through a bounding box for each vegetation unit, showing NDVI values, ranged between 0.00 (no vegetation) and 100.00 (healthiest vegetation), and vegetation typologies such as trees, shrubs and grass. This information allowed participants to identify where the site was healthy, organise a catalogue of vegetation typology, and detect where ecological functions might be weaker. The representation offered a shared basis for discussion, guiding priorities such as replanting, maintenance, or the design of continuous green corridors to improve connectivity.

Species monitoring

Understanding local fauna presence and habits is important for planners to identify zones that need protection or corridors that support species movement. Datasets are built with analysis results of image detection technique applied on the images collected through camera traps and with participant observations conducted through guided walks with experts and supported by apps such as iNaturalist¹¹. Species frequency, diversity indices, and temporal patterns are obtained and then converted into spatial

¹¹iNaturalist. "iNaturalist," n.d. <https://www.inaturalist.org/>

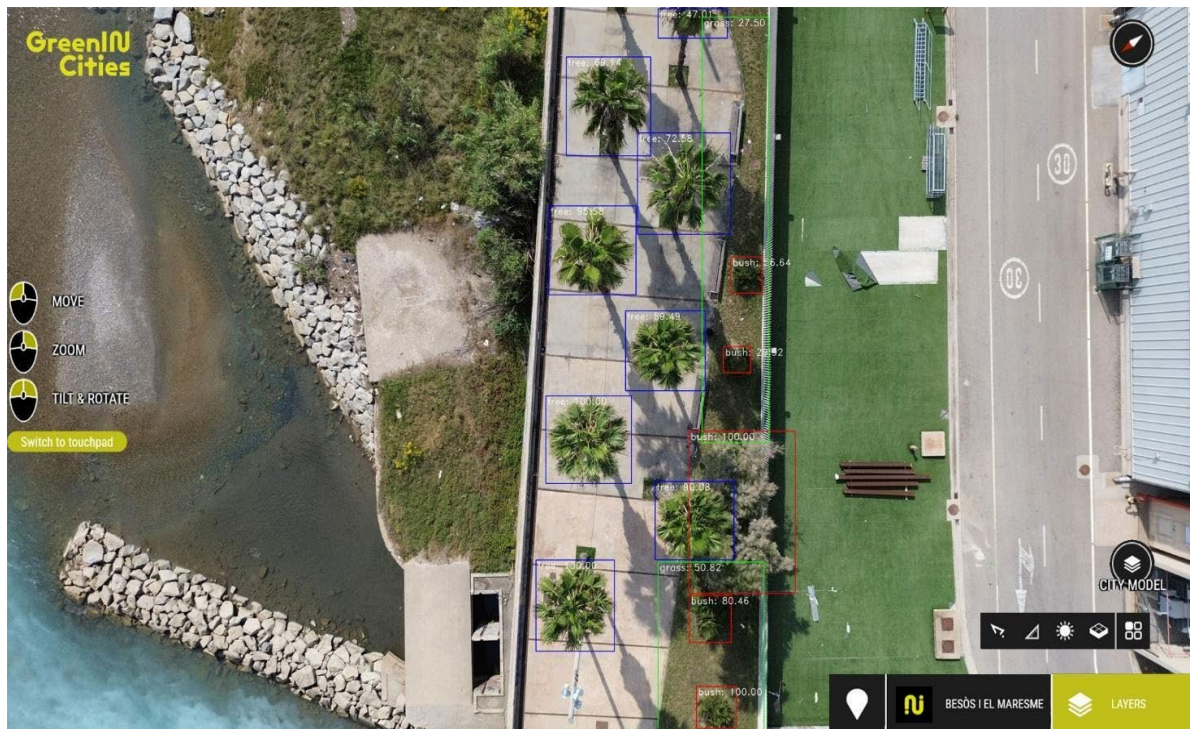


Figure 2: NDVI analysis and vegetation classification map visualised as a Digital twin layer.

heat maps showing areas of higher or lower species use and integrated in the digital twin for visualisation.

In the GreenInCities project, this workflow was applied through direct observation and highlighted the parts of the site most frequented by different species (e.g. near the river for terrestrial species), becoming a practical tool for citizens' engagement. It inspired and informed proposals for aerial species refuges, the definition of new ecological corridors near the river, and the redesign of lighting strategies to minimise disturbance in sensitive areas. Camera traps, expected to be deployed in the next months to expand the temporal and spatial resolution of species data, will add nocturnal and seasonal patterns to the participatory process.

Microclimate modelling

Microclimate conditions, such as temperature and noise levels, influence the comfort of urban areas not only for humans but also for other species. Urban designers can modify these conditions through interventions, for example by selecting specific pavement materials or increasing climate sheltered areas. AI-supported thermal modelling and environmental sensors are used to analyse comfort. Through computer vision and machine learning analysis of drone imagery or render of future scenarios, surface materials are classified and using physics-based AI models their thermal performance under site-specific conditions are estimated. IoT sensors (measuring air temperature, humidity, noise, and light levels) validate these simulations and provides real time data. This information is visualised into the digital twin through colour based thermal maps and dashboard boxes.

In GreenInCities, participants could directly explore which areas were heat-vulnerable and how design interventions might change outcomes. Thermal modelling revealed stark contrasts between surface types under summer conditions. Exposed concrete was simulated to reach up to 45–50 °C, while shaded



Figure 3: Local fauna detection outputs (terrestrial species) from direct observation and use of iNaturalist integrated into the digital twin as heat maps.

concrete stayed closer to 25–30 °C, and vegetated surfaces remained around 20–25 °C. This provided an evidence base for identifying hotspots, testing cooling strategies, and evaluating the implications of design interventions for both human and non-human comfort.

In fact, these variations have immediate ecological implications: for example, pollinators reduce activity above approximately 30–32 °C¹², while amphibians show stress above 35 °C¹³. This led to proposals for tree planting, shading shelters, and permeable materials, with early design simulations already demonstrating measurable improvements in surface temperatures. Future deployment of IoT sensors will validate and enrich these simulations, creating a real-time feedback loop for co-monitoring.

Results

The achieved results from applications of the methodological framework in the Barcelona pilot demonstrate how ecological signals, translated into indicators through technology, can influence urban design decisions that are both scientifically robust and participatory. NDVI analysis highlighted where vegetation is thriving or under pressure, heat maps of observed fauna revealed areas of ecological importance, and thermal modelling demonstrated how surface materials shape multispecies comfort areas. Communicating these results in a shared and interactive format, such as a digital twin, enabled citizens, experts, and policymakers to engage in discussions where non-human needs became visible and were incorporated as relevant design inputs.

¹²Koppert, Plant–Pollinator Interactions in High Temperatures, Glasshouse Consultancy, 2020.

¹³Patrice Pottier et al., “Vulnerability of Amphibians to Global Warming,” *Nature* 639 (2025): 954–61, <https://doi.org/10.1038/s41586-025-08665-0>



Figure 4: Map of surfaces temperature layer integrated within the digital twin as thermal map.

Conclusions

The application of the proposed methodological framework aimed to illustrate the kinds of design outcomes that can be achieved through multispecies co-creation, while also showing how participatory urban planning can become more inclusive with non-humans, ultimately enhancing ecological resilience in future cities and shifting participation from an anthropocentric exercise toward a multispecies negotiation.

An additional strength of this framework lies in its potential for validating design strategies. In fact, by continuous monitoring of ecological indicators after project implementation, the success of urban regeneration projects can be measured and eventual needs for adaptive management can be flagged. In this way, participation does not end with the design phase but continues through implementation and maintenance, keeping non-human needs present throughout the lifecycle of the project.

While further testing and scaling are required, the combined use of AI, digital twins, and participatory practices confirms both the feasibility and the added value of multispecies participation in urban design. By making non-human signals legible, the framework positions citizens not only as beneficiaries but also as allies and mediators for other species, paving the way toward cities that are more just, resilient, and ecologically attuned.

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